Subsurface Flow Wetland Treatment of Dairy Farm Stormwater

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[Editor's note: Charts and tables are located in the appendix section at the end of this paper.]

Abstract
Non-point source pollution from agriculture can cause chronic water quality impacts in small streams and downstream marine waters. In North Saanich, B.C., water quality sampling of a tributary of TENTEN Creek in February 2000 indicated excessive levels of nutrients, suspended solids and faecal coliforms present in stormwater originating from an adjacent dairy farm. The tributary from the farm crosses into lands managed by the Victoria Airport Authority (VAA). The WSIKEM-TENTEN Stewardship Project, working in partnership with VAA, Pendray Farms, Tseycum First Nation and Fisheries & Oceans Canada, developed a stormwater interception and treatment complex beginning in August 2000. A 2.1 million-litre stormwater detention pond was constructed with two piped outlets, one that fed a 150 metre long, 3-metre wide sub-surface flow constructed wetland. Monitoring of treatment efficacy in the winter of 2000-01 indicated that up to 99% of source faecal coliforms were removed, while nutrient and TSS reductions ranged from 25-95%. Subsequently a second wetland was constructed in 2001 to treat additional stormwater, and we estimate that during the first three years of operation, over 300 million litres of stormwater were treated. This paper discusses how the project was developed, its successes and limitations, and the role of stewardship partnerships in habitat and water quality restoration. Data describing wetland efficacy in treating agricultural stormwater is presented in tabular and chart formats, along with discussion of several of the water quality parameters that were investigated.

Introduction
Dairy farming presents significant challenges to the farmer and the environment. Although off-farm inputs of fertilisers and pesticides can be minimised through sustainable farming practices, some of these same practices can have impacts on surface water quality.

Intensive dairy farming requires considerable inputs of feed. Although milk and milk products are the desired outputs, waste, in the form of cow urine and faeces is another major production component. One of the basic tenets of sustainable agriculture is on-farm nutrient recycling. If utilising animal waste generated from on-farm crops can reduce fertiliser imports, then a closed-loop system will be approached. However, when the manure distributed onto the silage-crop fields is not bound up in plant material, soil organisms, or soil structure, it can pass out of the system as a component of stormwater.

Pendray Dairy Farms is located in North Saanich, B.C., near Victoria International Airport. This farm produces 8500 litres of milk per day year from 245 milked cows, with 500 animals altogether on site (Pendray, 2003). Faecal/urine waste from the barn cows is stored in an outdoor lagoon before being distributed by a sprayer truck onto fields adjacent to the barn, as well as onto airport lands. Approximately 67 hectares of the adjacent fields have a tile drainage system, which deliver excess field moisture to a central ditch (Figure 1). This stormwater was been found to contain high levels of sediment, along with significant nutrients and faecal bacteria resultant from the cow faeces and urine. The central ditch forms a tributary of TENTEN Creek after it leaves the farmer's property, about 2.5 km upstream of the marine receiving waters of Patricia Bay.

Non-point source pollution has many direct and indirect effects on freshwater ecosystems, from direct toxicity to organisms (nitrite, ammonia, sediment, low oxygen) to indirect impacts such as hyper-nutrification and resultant lethal and non-lethal effects.

Nearshore marine habitat is critical to the growth, development, and survival of juvenile salmonids. The local marine environments, like Patricia Bay, have suffered for several decades from terrestrial sources of contamination of runoff from residential, agricultural, and industrial stormwater. High faecal coliform contamination in the intertidal and near-shore waters have prompted shellfish contamination harvesting closure (Cameron & Miller, 2000), while excessive nutrients are known to reduce eelgrass beds and encourage unwanted algae to flourish.

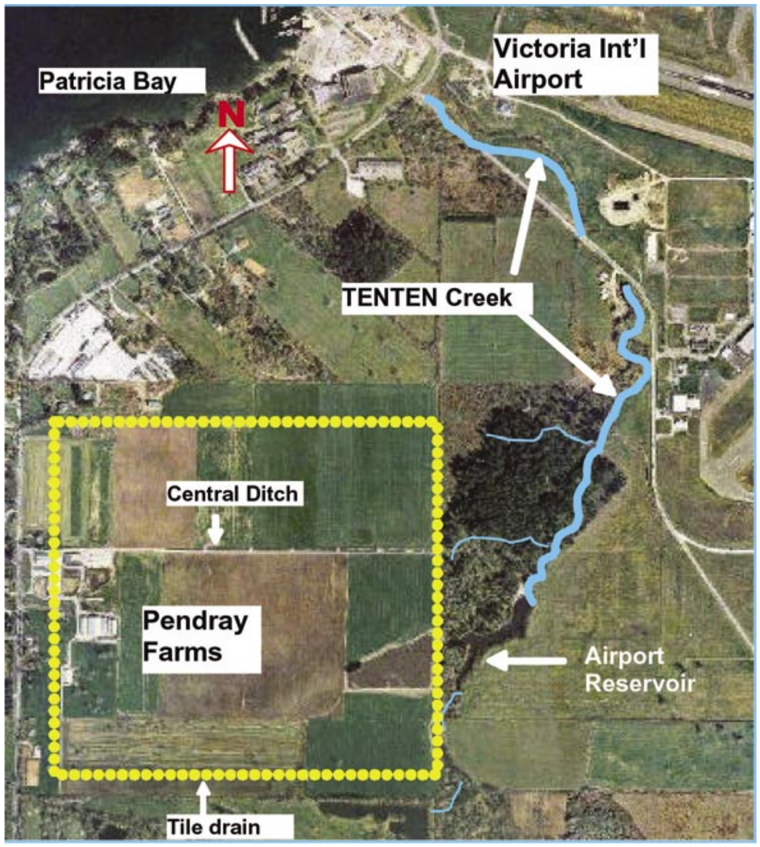

Figure 1. Lower TENTEN Creek Watershed—Pendray Farms & Airport, 2000

The WSIKEM-TENTEN Stewardship Project (WTSP), a stewardship partnership with VAA, Tseycum First Nation and Fisheries & Oceans Canada, was formed in 1996 to restore ecological function in both Tseycum and TENTEN Creek watersheds. By working cooperatively with Pendray Farms, and accessing funding primarily from Fisheries & Oceans Canada, WTSP constructed, operated and monitored a stormwater management pond and constructed wetland complex. The goal of the restoration project described here was to control and treat contaminated stormwater originating from Pendray Farms' fields for the restorative benefit of TENTEN Creek and the receiving waters of Patricia Bay.

SITE/PROJECT OVERVIEW

Area/Site Description & History

Description

TENTEN Creek is a small watercourse with a poorly functioning ecosystem. The watershed (6km^2 area) has been highly modified to suit the purposes of industry, agriculture and urbanisation. Its headwaters begin in John Dean Provincial Park on Mount Newton, and runs through residential areas, farmland, a golf course, and an airport before emptying into Patricia Bay, Saanich Inlet (Figure 1).

History

Prior to the 1950s, TENTEN Creek supported viable salmonid populations of coho salmon (*Oncorhynchus kisutch*) as well as anadromous cutthroat trout (*Oncorhynchus clarkii*) (Parks 1998). The only species of fish found by the author in TENTEN Creek was a vestigial, likely transient population of stickleback (*Gastrerosteus aculeatus*). According to Chief Vern Jacks of the Tseycum Indian Band, the traditional land users of TENTEN Creek, the last recorded sightings of salmonids in TENTEN Creek was in 1953. (Jacks 1999; Parks 1998). Water quality and sediments have degraded to point that TENTEN Creek is no longer capable of supporting self-sustaining populations of coho salmon and cutthroat trout (Halwas[1] 1999; Halwas[2] 1999).

Project Genesis – A Stewardship Initiative

Once initial water quality testing in February 2000 determined that stormwater quality was very poor (Appendix, Table A-1), an on-site meeting with Mr. David Pendray was held. The author, as project coordinator for the WTSP, presented him the results of the water quality sampling and suggested that a stormwater management pond and constructed treatment wetland might be able to improve water quality.

The project coordinator then conferred with other members of the WTSP and a joint decision was made to apply for funding to begin the pond/wetland complex construction in the summer of 2000. Funding was received from the Habitat Restoration & Salmonid Enhancement Program (HRSEP) of Fisheries & Oceans Canada for the fiscal year 2000-01, and subsequently for 2001-02.

METHODS

Siting of Works

The proposed site for the pond and wetland was in the area immediately east of Pendray fields on property owned by Transport Canada, designated "Airport Reserve Lands".

A significant objective in siting the pond and wetlands was minimising impacts on mature trees. The construction areas were selected to 'fit' within swamp thicket areas, which were already wet and had few mature conifers.

Pre-construction & Initial Design Considerations

In early August 2000, volunteer crews organised by a neighbouring stream group salvaged native plants from the proposed pond site. More than 800 plants were transplanted to Graham Creek, in Centennial Park, in Central Saanich.

The pond was designed to function for 2.1 million litres of stormwater detention, filling up during, and drawing down between rain events, intending to catch and treat 'first flushes'. This pond is an expansion of the 'forebay' concept recommended by many wetland authors and design manuals (State of Virginia, 1999). Forebays trap sediment that might otherwise overload the wetland and provide a control structure for distribution of water to the wetlands.

The first wetland was designed on a standard 'subsurface flow' (SF) concept, primarily utilising information found in Reed (1993), and Hammer (1991). SF wetlands are constructed in rectangular cells filled with a treatment media such as coarse rock and gravel. SF systems also incorporate plants such as bulrushes, cattails and reeds. Stormwater filtered throughout the gravel remains unexposed to the atmosphere. Water treatment occurs at microsites in the plant roots and within the soil matrix. Both aerobic and anaerobic bacteria are attached to the surfaces of the rock, gravel and plant root hairs where they actively purify wastewater (Pries, 1994).

Before construction began, the design capacity of the pond and wetland system was known to be insufficient to treat all of the stormwater delivered from the target fields: peak flows in excess of 40 m^3/minute could be expected in a 1-in-50-year event (Environment Canada, 2003). If this pilot project was successful in its first year, the design provided the flexibility to expand to include a second wetland.

Construction - 2000

Pond

The area for the pond was cleared of vegetation and the 15 – 25 cm soil overburden was stockpiled nearby. Patches of *Carex obnupta* sedges were laid aside for later transplantation into the wetland. The glacio-marine clay subsoil was determined to be good berm construction material, therefore 30 cm 'lifts' of clay were packed with a bulldozer. This process increased the height of the berm as the pond was dug to a final depth of 4.5 metres.

Inlet Channel

The slope on the clay-based inlet channel was 0.05%. A rock and grout spillway was constructed to prevent pond sidewall erosion during pond filling. The entrance to the inlet channel was set at the same grade as the main Pendray ditch.

Wetland #1

Following clearing and overburden removal to a clay base, the wedge-shaped wetland area was capped in clay from the pond. Channel width of 3.5 metres was the same as the width of the geotextile used to separate the gravel from the soil. In order to maximise the channel length for treatment, the five channels were excavated in a continuous meander pattern.

Figure 2. Wetland #1—May 2001

The bottom, longest channel segment was dug first, with the lowest grade (~0.05%). The next four channel segments were shorter in length and increased from 0.1% to 1% grade towards the top of the slope. Above the top channel, there was 5-metre entrance area that was graded to a 0.5% slope, leading into the first channel segment.

After each section of channel had been excavated, the packed clay channel bottom was covered in 5 –7 cm of 'pit run,' a mixture of unsorted sand and gravel, to prevent upward mobilisation of the clay into the media layer. The media layer was 10 – 20 cm of 1-1.5 cm drain rock, purchased from a local quarry. This layer was covered by the geotextile before the overburden soil was applied at a depth 15-25 cm.

Salvaged *Carex obnupta* sedges were planted on 0.75 m centres throughout the channels, within the soil but above the surface of the geotextile cloth. The 150-m long by 3.5m wide channel had a total surface area of 525 m^2 (Figure 2.) The overall wetland complex is pictured in Figure 2. below.

The pond berm was cut open in two places to install 200mm pipes to deliver water from the pond to Wetland #1 and a second wetland if built in the future.

Site Completion Activities
All exposed clay berms on the pond and the wetland were planted with a mixed grass seed mix enhanced with white clover and fall rye seed. The pond end of the outlet pipe was screened and on the wetland pipe ends, gate valves were installed.

Operation and Monitoring – Fall - Winter 2000/2001
After the pond began to fill in October 2000, water was released to the wetland. Water quality monitoring began immediately to gauge water quality coming from the farm, and the efficacy of the wetland treatment.

Construction - 2001

A second wetland was constructed in the late summer of 2001 with funding from HRSEP. The second wetland was required to increase stormwater treatment capacity and to test new methods of wetland channel construction.

Wetland #2
Wetland #2 was designed to process 350 litres per minute (lpm), considerably more capacity than Wetland #1's optimum flow capacity of 150 lpm. As with the pond and Wetland #1, siting of Wetland #2 respected forest values by taking advantage of an old fluvial channel bed. Following analysis of the site contours and studying the vegetation, Wetland #2 was built 7-metres wide by 70-metres long, for a total surface area of 490 m^2 or about 7% less than Wetland #1.

Figure 3. Wetland #2. Media gravel and geotextile.

The upper end Wetland #2 was excavated 3m down into the clay subsoil. The base grade of the first 30m of the channel was inverted at a slope of 1%. The final 40m of the channel after the bend was sloped at 0.05% after offsite clay was used to build up the lower end of the channel. Pit run again formed the underlayer but larger gravel (2 – 5 cm) salvaged from the roof replacement at the Institute of Ocean Sciences was used as the media layer. The gravel varied in depth from 80 cm at the head of the channel where the slope was inverted, to 50 cm deep at the distal end. The same geotextile was used between the media layer and the alternate 20 – 30 cm planting layer of 'birds-eye" pea gravel (3-7 mm)(Figure 3).

Large concrete blocks supported the elevated clay channel at the end of Wetland #2. The upper end of Wetland #2, which had considerable light penetration, was planted in *Scirpus microcarpus* (small-flowered bulrush). The shadier, lower section of the wetland was planted with *Carex obnupta*.. Plantings were spaced on 0.75m centres.

Overflow Channel

Preparation for a channel to take excess stormwater from the pond to the Airport Reservoir was made during September 2001. Trees and overburden were removed and clay was imported to provide an impervious base. This channel has not been completed to date. The overall complex is presented in Figure 4 below.

Construction – 2002

In 2002, funding from the Pacific Salmon Foundation was used to modify the outlet structures for both wetlands. A perforated aluminium 'splash pan' structure installed to aerate the water exiting the Wetland #1, and the outlet to the stream was gravelled and terraced to prevent erosion. Wetland #2 outlet reconstruction entailed removing the end supporting blocks and terracing the outlet in three steps.

Water Quality Monitoring

The waters of pond inlet, wetland inlets and wetland outlets were sampled for several parameters over using a variety of methods and equipment detailed below. Personnel from the Tseycum First Nation Fisheries Program were trained extensively in sampling methods and analysis techniques by staff from the Institute of Ocean Sciences and WTSP.

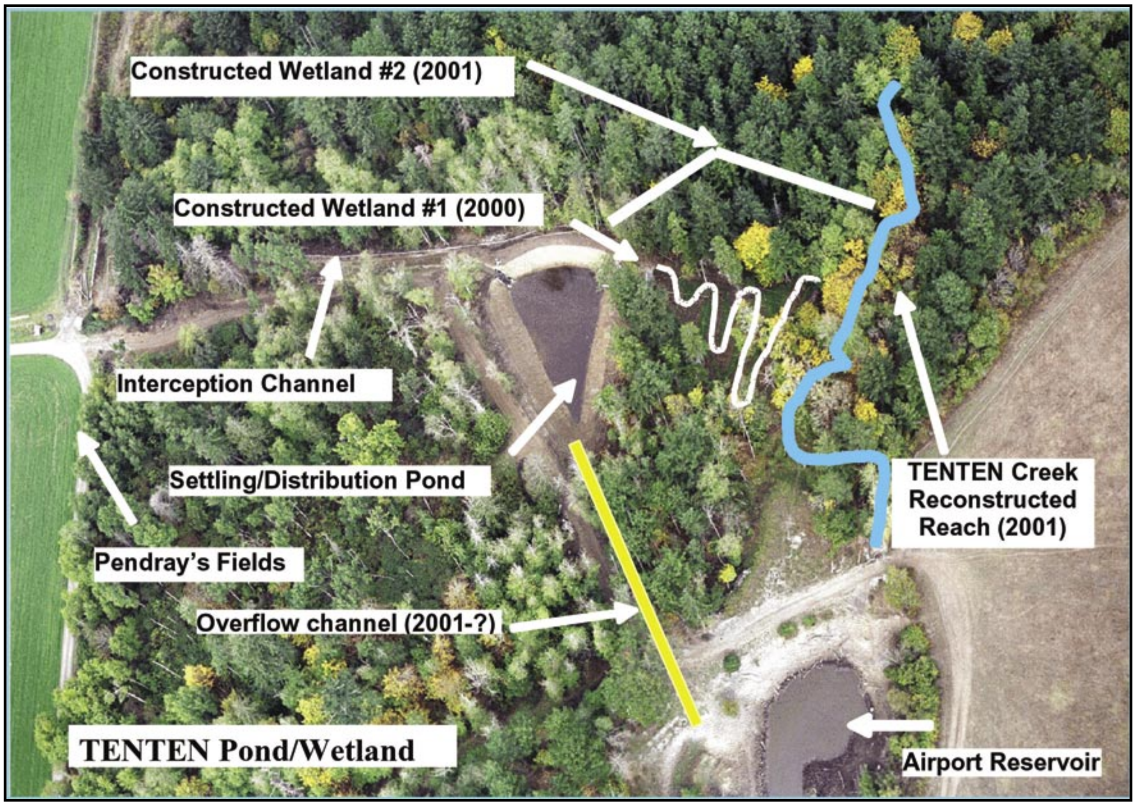

Figure 4. Pond/Wetland complex.

Physical/Chemical Parameters

Weather during and proceeding sampling, time, date and person(s) of sampling and observations of pond inlet condition (low, medium, high) were recorded on field data sheets.

Temperature

Air and water temperatures were measured onsite using the temperature feature of a YSI Model 55 Handheld Dissolved Oxygen System[1]. This Thermistor-type sensor has an accuracy of +/- 0.2°C and a resolution of 0.1°C.

Turbidity

Turbidity was measured in the field with a Smart Colorimeter[2] analyser in Formazin Turbidity Units (FTU), which are analogous to Nepelometric Turbidity Units (NTU). Turbidity measurement is a field method of estimating Total Suspended Solids (TSS) without filtering, dehydrating and weighing solids.

Conductivity

Conductivity was measured using a Pinpoint[3] Conductivity meter. Conductivity is a similar measure to Total Dissolved Solids (TDS), but simpler to determine in the field.

pH

pH was measured using a Pinpoint[3] pH meter until March 2002, when an Oakton pH Testr2[4] was substituted.

Flow rates

Flow rates of the wetland inlets were determined by a measuring bucket and stopwatch, with the average of five timings used to calculate flow rate in litres per minute. After each flow measurement, the valve on the outlet pipes were adjusted up or down to provide a different flow rate to the wetlands, to test treatment efficacy over a range of flows. The pond inlet channel flow rate was not determined.

Dissolved Oxygen

Dissolved oxygen was measured in percent saturation and concentration (mg/l) using the YSI Model 55 Handheld Dissolved Oxygen meter.

Nutrient Parameters
Nitrate-nitrogen, nitrite-nitrogen, potassium and orthophosphate were measured using the Smart Colorimeter[2] analyser in a lab at the Institute of Ocean Sciences. Ammonia-nitrogen was determined onsite the same equipment.

Bacteriology
Faecal coliform and faecal enterococcus bacteria were determined by membrane filtration standard methods by MB Labs Ltd, Sidney, B.C.

Operation & Maintenance

Routine Wetland operation in the first two years of operation included regular water quality monitoring and inlet flow adjustments. Occasionally, adjusting flow into the inlet channel from the Pendray tributary with sandbags was required, as was annual accumulated sediment removal from the head of the inlet channel.

Wetland and pond berm grasses and legumes were cut with a power trimmer to prevent seeding into the wetland and to encourage root growth. In Wetland #1 channel, unwanted vegetation from the seed bed was removed by hand pulling and raking, reducing competition with the *Carex obnupta.* The dead leaves of *Scirpus microcarpus* plated in the upper part of Wetland #2 were removed in 2003 while other invading species were hand weeded.

In the fall of 2001, chicken wire fencing was installed on the eastern end of the pond to discourage muskrats (*Ondatra zibethicus*) from tunneling into the pond berm.

[1]YSI Incorporated, Yellow Springs, Ohio USA 45387
[2]LaMotte Company, Maryland, U.S.A. 21620
[3] American Marine Inc. U.S.A
[4]LaMotte Company, Maryland, U.S.A. 21620

RESULTS

Results of environmental conditions during water quality sampling, and analysis of water leaving the farm ("Pond Inlet"), entering the wetlands from the pond ("Wetland Inlet") and exiting the wetlands ("Wetland Outlet") are provided in the Appendix Tables A1 – A5. Minor statistical analyses of means, standard deviation, and medians are provided. Charts that illustrate the changes of selected parameters between the start and end of each wetland are presented for pH, turbidity, total nitrogen, total ammonia, un-ionized ammonia, nitrate, nitrite, orthophosphate, and faecal coliform bacteria.

Water quality guidelines for certain parameters presented in this report have been derived from many different sources. No one jurisdiction has a complete 'suite' for the selected parameters. These parameters, their guidelines, their category of protection and their source are listed in Table 1. Priority was given to those guidelines developed for British Columbia and Canada, and for the protection of "aquatic health". The nitrate guideline was developed for salmonid hatcheries, and may be more restrictive than those for freshwater aquatic health. Since an overarching goal of the WTSP is to eventually restock TENTEN Creek with coho salmon, the use of this guideline is appropriate. For the nutrient parameters total ammonia, un-ionized ammonia, nitrate, nitrite, and orthophosphate, Tables A-1 to A-5 have values printed in red exceed the guidelines in Table 1. These guidelines are also used in the respective Charts in the Appendix.

Table 1. Water Quality guidelines.

Parameter	Guideline	Category	Source
pH	6.5 - 9.0	freshwater aquatic life	CCME[1] (2003)
Turbidity	< 25 NTU	freshwater aquatic life	Harvey (1989)
Total Ammonia	1.4 - 2.2 mg/l	freshwater aquatic life	CCME (2000)
Un-ionized Ammonia	< 2 μg/l	freshwater aquatic life	USEPA (1985)
Nitrate (NO_3)	13 mg/l	freshwater aquatic life	CCME[2] (2003)
Nitrite (NO_2)	0.06 mg/l	freshwater aquatic life	CCME[1] (2003)
Orthophosphate	0.1 mg/l	aquatic life	USEPA (1986)

Pond Inlet and wetland sampling events were generally scheduled on different days due to sampling and analysis time constraints.

Many water quality parameters were exceeded during first flush events in the fall (October – November) and then again in the spring (March – April). This would be expected as Pendray Farms distributes manure on the fields just after corn harvest in September and October and before the first significant rains. Pendray Farms halt fertilising until the spring, beginning again in March, but avoiding rain events when possible.

DISCUSSION

Water Quality Parameters

pH

Pond Inlet pH ranged from 4.56 to 8.80, with the former level being significantly below CCME[1](2003) minimum guideline for freshwater aquatic life of 6.5. Wetland #1 and #2 both demonstrated a moderating effect on pH, where high Inlet pH values were reduced and low Inlet pH values were increased during passage (Chart 1,2). The trend generally was one of decreasing pH, which would be consistent with anaerobic processes within the wetlands. On a few occasions, Wetland #1 caused decreases in pH below the 6.5 recommended by CCME[1](2003). Values for pH for the Pond Inlet and Wetland Inlets were generally acidic to neutral (pH=7) during the fall and early winter, becoming increasingly alkaline through the late winter and into spring.

Turbidity

Turbidity values for Pond Inlet and the Wetland Inlets were consistently over the 25 NTU guideline (Harvey, 1989). The highest value of 313 was measured for Pond Inlet on April 17, 2001, although most of the high turbidity events were associated with fall and winter storm events (Table A-2). Although it was expected that the pond would reduce turbidity by settling out larger sediment fractions, the data shows a higher mean and median turbidity for the Wetland Inlets than for Pond Inlet. This is possibly explained by spring blooms of phytoplankton and zooplankton in the pond that could cause an increase in turbidity. As well, as Pond Inlet was often measured on different days than the Wetlands, the results could be a reflection of day-to-day variance. On certain days when Wetland #1 was sampled concurrently with Pond Inlet, there was a large reduction in turbidity (ie: Nov-28-01: 221 *vs* 88).

The Wetland performance on reducing turbidity is clearly demonstrated in Chart 3 & 4, where consistent reduction is indicated, although Wetland #1 appears more efficient in reducing turbidity. In many instances, neither wetland was capable of reducing turbidity below the 25 NTU standard.

Total Ammonia ($NH_3 + NH_4^+$)

Pond Inlet and Wetland Inlet total ammonia levels were highest during first flush events in the fall. Where total ammonia levels exceeded the 1.4 mg/l guideline (CCME, 2000) by a small amount, the wetlands were generally successful in reduce them to below 1.4 mg/l (Chart 5, 6).

Both wetlands demonstrated large reductions in total ammonia when inlet levels were very high. On November 1, 2001, total ammonia increased in Wetland #1 from 10.40 mg/l to 15.86 mg/l, while on November 7, Wetland #2 raised total ammonia from 4.42 mg/l to 5.07 mg/l. Reed (1993) reports that some SF wetlands are known to show negative ammonia removals due to their particular structure. Reed (1993) also reports that SF wetlands that had no algae present, high retention times, and good root penetration have the best ammonia removal rates.

Un-ionized Ammonia (NH_3)

Reed (1993) states that for wetlands, “The removal of non-ionized ammonia is typically the major nitrogen parameter of concern due to its toxicity for fish and other aquatic animals...”. The trend in pH noted above, where springtime pH rises, induces a significant increase in NH_3. Chart 7 shows Wetland #1 significantly reducing NH_3 levels in the spring of 2001.

Nitrate

Nitrate (NO3-) is a measurement of the most oxidized and stable form of nitrogen in water. Nitrate is the primary form of nitrogen used by plants. The Canadian Council of Ministers of the Environment have recently published a maximum value of 13 mg/l as a guideline for the protection of freshwater aquatic life from direct toxic effects of the nitrate ion (CCME[2], 2003). This does not consider indirect effects due to eutrophication.

Charts 9 & 10 indicate that the wetland has a considerable reductive effect on nitrate levels, to the benefit of the overall downstream watershed. However, the guideline of 13 mg/l is consistently exceeded by both treated and untreated stormwater from Pendray Farms.

Nitrite

Nitrite is a compound that has a strong negative effect on aquatic life, hence its relatively low guideline of 0.06 mg/l (CCME[1], 2003). In both Wetland #1 and #2, significant reductions in nitrite concentrations were noted (Charts 11, 12). In many cases, Wetland #1 reduced nitrite below the guideline. Wetland #2 appeared less efficient in reducing nitrite, but this may be a function of wetland 'maturity'.

Total Nitrogen

Total nitrogen reduction was a goal of this project. As with other parameters, first flush events appear to have the highest concentrations. Consistent reductions in total nitrogen are demonstrated in both wetlands (Charts 13, 14).

The fate of the nitrogen removed from the wetlands is unknown. Some nitrogen was likely taken up by wetland vegetation. As well, nitrogen was likely utilised by facultative bacteria, for energy and growth, within the wetland gravel media. Some nitrogen may have been converted to N_2 to cycled back into the atmosphere. This latter event would be a desirable function of the wetlands, as no accumulation of nitrogen within the wetland would occur.

Orthophosphate

Phosphate is well known to cause pollution problems in freshwater systems as an unwanted algal promoter. Similar to nitrate, it is not believed to be as significant factor at TENTEN Creek. The wetlands moderately reduced orthophosphate but on two occasions in March & April 2001, significantly increased orthophosphate concentrations (Charts 15,16).

Faecal Coliform Bacteria

Faecal bacteria from both human and agricultural sources have led to a fifteen-year closure for harvesting of shellfish in Patricia Bay. The standard test for contamination is faecal coliforms. Cow manure contains coliform bacteria that can contaminate fresh water and near-shore marine waters. A goal of this project, particularly from the Tseycum First Nations perspective, was to reduce faecal coliform levels in TENTEN Creek, thus reducing the load entering Patricia Bay to the detriment of shellfish harvest opportunities.

Both wetlands reduced faecal coliforms (Charts 17 & 18). Wetland #1 immediately provided a significant decrease in faecal coliforms. Up to three orders of magnitude of reduction were consistently achieved. This immediate and profound faecal reduction was a major factor in securing funding to continue with this project.

In the first sampling of the second year of Wetland #1 operation (Oct-26-01), faecal coliform increased by a significant amount. It is hypothesised that this first flush event washed out rodent faeces from within the wetland that had built up over the summer.

Both wetlands demonstrated similar reductions in faecal enterococcus bacteria.

Vegetation

Carex obnupta for Wetland #1 and the lower end of Wetland #2 seems to have been a good choice. Lateral rhizome growth has filled in considerable area between the original plantings. Root penetration of the geotextile was extensive, occurring much earlier than expected. However, some *Carex obnupta* plants in Wetland #1 turned yellow and died in 2002. As well, competition from some of the plants that arose from the overburden seedbed has inhibited some *C. obnupta* growth and survival.

Scirpus microcarpus appears to have survived well in the upper section of Wetland #2, with the plants reaching 1.5m tall in the fall of 2002. Rhizomatic growth of the plants has led to many new shoots in the spring of 2003. Root penetration though the geotextile by *S. microcarpus* was noted but these were still small roots, under 3 mm in diameter. *Scirpus spp.* is noted by Reed (1993) to have a root penetration depth of 0.8 m, and was more efficient in reducing BOD, turbidity, and ammonia than cattails (*Typha spp.*) or reeds (*Phragmites spp.*).

SUMMARY

Biological Oxygen Demand (BOD) is a standard measure of wetland performance, but was not measured for this project because of lab facility limitations. In future wetland investigations, sampling for Chemical Oxygen Demand (COD), if not BOD should be undertaken.

The total amount of stormwater treated by the two wetlands between October 2000 and March 2003 is estimated to be in excess of 300 million litres. This was less than optimum as different flow rates were utilized for performance rating purposes. It appears that Wetland #1 has an optimum flow rate of 150 lpm, while Wetland #2 optimum flow rate is 350 lpm. If the wetlands are operated at these levels, it is expected that 120 million litres of water can be processed annually. Although this is only about a third of the average expected cumulative rainfall on the tile drained acreage, the wetlands are processing most of the worst quality water, particularly first flush events (Environment Canada, 2003).

The total cost of the project described herein (including monitoring) was \$117,000 CDN, of which \$37,000 was from in-kind contributions

Construction on an overflow channel was begun but not finished due to funding constraints. The overflow intended to pass stormwater in excess of the wetland processing capability (~500 lpm) through the pond and into the Airport Reservoir (Figure 4). Recently an alternate proposal suggested diverting this excess stormwater into the "swamp thicket" to the south of the complex. This 2 ha area would process the stormwater as a free surface flow wetland before the stormwater would re-enter the system through the Airport Reservoir.

Occasional water quality monitoring should be undertaken in the future. Routine operation of the intake structure and wetland intake pipe valves is expected of Pendray Farms. Maintenance activities such as clearing fallen trees, wetland vegetation removal and other tasks should be taken over by Pendray Farms, or by the landowner, Transport Canada, or by their tenant, Victoria Airport Authority.

CONCLUSIONS

Water quality monitoring of this project has clearly demonstrated the efficacy of the wetland complex in reducing harmful compounds before they reach natural waters.

The author concludes and believes that this project has been a success on many levels, besides treating water. It has helped bring together many members of the WTSP in achieving common goals of habitat restoration through water quality improvement. It has demonstrated to many local farmers that environmental initiatives are not to be feared and rejected by rote. First Nations' people have learned new marketable skills and increased their personal technical skills.

ACKNOWLEDGEMENTS

I would like to acknowledge and thank the following people and organisations that have helped make this constructed wetland project a success:

The Pendray Family; Terry Stewart (VAA); Chief Jacks and members of the Tseycum First Nation;
Robin Brown, Brian Smiley, Tom Rutherford, Jonathan Joe, Fisheries & Oceans Canada; Arbutus Grove Nursery; Dr. Don Eastman, Director, Restoration of Natural Systems Program, U. of Victoria.

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APPENDIX – TABLES & CHARTS

Table A-1. Pond Inlet Data - February2000 - May 2002

Date of sample	Time of field sample	Air Temp. °C	Stream Flow Condition	Weather Proceeding	Weather During	Dissolved Oxygen (%Sat.)	Dissolved Oxygen (mg/l)	Water Temp. °C	Conductivity (µS)	pH	Tur bidity (FTU)	Amm onia Nitrogen (mg/l)	Total Amm onia (mg/l)	Un-ionized Ammonia (µg/l)	Nitrate Nitrogen (mg/l)	Nitrate (mg/l)	Nitrite Nitrogen (mg/l)	Nitrite (mg/l)	Total Nitrogen (mg/l)	Phos phate (mg/l)	Potas sium (mg/l)	Fecal Coliform (CFU/ 100ml)	Fecal Entero Bacteria (CFU/ 100ml)
4-Feb-00	n/s	n/s	n/s	n/s	n/s	55%	6.67	6.7	540	6.77	77	1.05	1.37	1.13	3.40	14.96	0.17	0.56	4.62	0.59	n/s	245	n/s
20-Oct-00	10:55	n/s	med	H. rain	cloudy	33%	3.12	16.6	875	7.13	218	1.60	2.08	8.50	7.20	31.68	2.00	6.60	10.80	2.5	n/s	180000	n/s
14-Nov-00	15:15	n/s	low	L. rain	Dry	86%	10.51	6.6	861	7.45	24	4.22	5.49	21.56	2.84	12.50	0.07	0.23	7.13	2	n/s	n/s	n/s
23-Nov-00	14:30	11.5	low	L. rain	Dry	43%	5.16	7.3	902	7.38	80	6.50	8.45	29.91	1.57	6.91	0.00	0.00	8.07	5.1	n/s	35600	249600
8-Dec-00	12:55	4.5	high	cloudy	cloudy	68%	8.06	7.8	580	6.40	12	0.32	0.42	0.16	16.30	71.72	0.35	1.16	16.97	0.6	n/s	8	808
13-Dec-00	10:45	1.2	low/med	frost/dry	frost/dry	76%	9.85	4.3	829	6.81	11	1.38	1.79	1.34	22.20	97.68	0.05	0.17	23.63	0.54	n/s	68	2200
20-Dec-00	10:30	3.8	low/med	L. rain	light rain	59%	7.33	5.7	750	6.02	25	0.54	0.70	0.10	7.12	31.33	1.00	3.30	8.66	0.29	n/s	226	607
3-Jan-01	9:15	5.9	low/med	clear	cloudy	58%	7.11	6.7	811	6.35	14	1.20	1.56	0.49	14.30	62.92	0.80	2.64	16.30	0.9	n/s	2	49
31-Jan-01	9:17	7.0	low/med	L. rain	cloudy	67%	8.26	6.5	653	6.42	63	0.76	0.99	0.36	2.82	12.41	0.00	0.00	3.58	0.41	n/s	48	14
21-Feb-01	8:45	3.7	low/med	sunny	sunny	76%	9.63	5.5	740	6.62	78	0.88	1.14	0.61	9.40	41.36	0.04	0.13	10.32	0.67	n/s	120	86
28-Feb-01	9:00	4.3	low	cloudy	cloudy	77%	9.87	5.1	705	6.83	24	1.41	1.83	1.54	10.20	44.88	0.06	0.20	11.67	0.56	n/s	42	32
7-Mar-01	10:00	11.8	low	sunny	sunny	77%	9.34	6.9	702	6.57	21	0.71	0.92	0.49	8.40	36.96	0.06	0.20	9.17	0.47	n/s	146	164
14-Mar-01	10:45	7.0	low	L. rain	cloudy	83%	9.74	8.1	691	6.84	25	0.83	1.08	1.18	10.70	47.08	0.11	0.36	11.64	0.48	3.3	70	52
21-Mar-01	9:30	5.2	med	overcast	sunny	71%	8.32	8.1	618	6.51	48	0.48	0.62	0.32	12.70	55.88	0.06	0.20	13.24	0.37	3.7	800	1400
4-Apr-01	9:10	6.1	low	sunny	cloudy	75%	9.13	7.0	654	6.76	72	1.15	1.50	1.24	14.00	61.60	0.05	0.17	15.20	0.71	4.9	159	136
12-Apr-01	10:10	6.9	low	cloudy	light rain	80%	9.42	8.2	705	7.02	23	0.80	1.04	1.73	12.00	52.80	0.11	0.36	12.91	0.71	7.3	96	92
17-Apr-01	13:10	12.6	low	rain	sunny	58%	5.83	14.7	582	6.82	313	0.00	0.00	0.00	1.83	8.05	0.03	0.10	1.86	0.55	2.7	20200	1264
25-Apr-01	10:35	14.2	low	sunny	sunny	135%	12.85	16.5	672	7.28	25	0.42	0.55	3.12	7.20	31.68	0.23	0.76	7.85	0.78	3.8	44	12
11-May-01	9:40	12.4	low	sunny	sunny	99%	10.00	15.1	689	7.11	18	0.75	0.98	3.40	7.30	32.12	0.11	0.36	8.16	0.92	4.1	143	367
18-May-01	9:00	14.5	low	sunny	sunny	77%	8.07	13.5	757	7.02	19	2.01	2.61	6.57	2.98	13.11	0.09	0.30	5.08	4.2	8.3	600	11600
30-May-01	10:00	10.9	low	cloudy	light rain	91%	9.51	12.8	713	7.08	20	0.25	0.33	0.89	7.40	32.56	0.25	0.83	7.90	1.68	3.9	9600	2150
8-Jun-01	13:10	n/s	low	cloudy	sunny	41%	4.11	15.3	609	7.33	20	1.03	1.34	7.85	5.30	23.32	0.24	0.79	6.57	5.7	6.2	4200	2670
13-Jun-01	13:15	n/s	low	cloudy	sunny	n/s	n/s	n/s	739	7.11	33	2.60	3.38	n/s	12.40	54.56	0.09	0.30	15.09	4.4	6.0	609	7000
26-0ct-01	9:30	9.7	low	rain	overcast	n/s	n/s	9.9	1407	6.20	249	2.00	2.60	0.75	n/s	n/s	n/s	n/s	n/s	15.9	n/s	129600	780800
1-Nov-01	11:15	10.9	low	L. rain	sprinkle	10%	1.05	11.1	682	6.32	45	3.10	4.03	1.68	0.02	0.09	n/s	n/s	n/s	3.3	21.0	600	43200
6-Nov-01	11:07	8.7	n/s	rain	sunny	7%	0.82	9.1	n/s	6.65	49	6.90	8.97	6.84	0.51	2.24	0.11	0.36	7.52	6.2	3.8	48000	7200
15-Nov-01	10:30	11.2	high	rain	rain	32%	3.59	10.6	n/s	5.89	175	1.80	2.34	0.35	2.68	11.79	0.20	0.66	4.68	0.8	5.4	42400	42400
28-Nov-01	10:00	4.7	high	rain	snow	37%	4.49	6.9	n/s	5.88	221	1.06	1.38	0.15	28.40	124.96	0.25	0.83	29.71	0.2	5.1	29600	470400
5-Dec-01	9:30	6.0	high	rain	sunny	31%	5.59	7.2	519	5.78	149	0.34	0.44	0.04	13.20	58.08	0.41	1.35	13.95	1.4	4.4	10400	81600
20-Dec-01	9:30	4.7	low	cloudy	cloudy	49%	6.07	6.0	401	7.00	44	0.50	0.65	0.87	11.00	48.40	0.20	0.66	11.70	3.8	5.3	111	32
3-Jan-02	9:00	7.9	high	rain	rain	31%	3.79	7.4	520	6.33	116	0.62	0.81	0.26	7.40	32.56	0.13	0.43	8.15	3.5	9.3	1600	112
17-Jan-02	10:45	4.1	low	cloudy	cloudy	64%	7.93	5.8	765	5.58	28	0.93	1.21	0.06	7.90	34.76	0.10	0.33	8.93	0.59	3.2	94	786
30-Jan-02	10:20	2.3	medium	rain/snow	cloudy	40%	4.98	2.9	776	6.85	53	0.84	1.09	0.80	9.50	41.80	0.24	0.79	10.58	0.66	6.4	1000	11800
14-Feb-02	10:00	6.5	low	sunny	sunny	81%	9.94	6.3	532	4.56	24	0.72	0.94	0.00	7.50	33.00	0.06	0.20	8.28	0.59	5.6	38	34
27-Feb-02	13:30	6.8	low	sunny	cloudy	54%	6.30	8.5	363	6.42	45	0.34	0.44	0.19	5.90	25.96	0.04	0.13	6.28	0.26	3.1	66	120
14-Mar-02	13:00	8.1	High	rain	cloudy	59%	6.95	8.5	190	n/s	157	0.14	0.18	n/s	1.72	7.57	0.03	0.10	1.89	0.56	5.8	3200	3800
28-Mar-02	10:15	8.5	low	cloudy	cloudy	133%	14.92	10.3	280	8.80	94	0.36	0.47	49.58	2.12	9.33	0.04	0.13	2.52	0.34	4.3	105	212
4-Apr-02	9:00	8.1	high	sunny	sunny	58%	6.82	7.5	410	7.80	19	0.76	0.99	9.29	2.37	10.43	0.07	0.23	3.20	0.43	3.6	600	304
10-Apr-02	10:20	10.6	high	rain	cloudy	130%	14.25	11.5	280	7.90	14	1.63	2.12	34.15	1.08	4.75	0.06	0.20	2.77	0.67	3.6	339	40
17-Apr-02	8:45	9.8	m	rain	cloudy	78%	8.80	9.4	n/s	7.50	57	0.66	0.86	4.72	0.87	3.83	0.06	0.20	1.59	0.37	3.8	299	2200
25-Apr-02	11:35	13.1	low	sunny	sunny	130%	14.30	11.2	n/s	7.70	13	0.40	0.52	5.20	2.85	12.54	0.09	0.30	3.34	0.97	4.2	82	n/s
9-May-02	9:30	19.0	low	cloudy	sunny	97%	9.79	14.9	n/s	7.70	45	1.45	1.89	24.96	2.72	11.97	0.11	0.36	4.28	2.13	3.1	800	136
27-May-02	13:35	17.6	low	sunny	cloudy	79%	7.68	16.5	n/s	7.40	11	7.00	9.10	68.52	10.00	44.00	0.17	0.56	17.17	2.78	4.2	14	141
				Mean		68%	7.80	9.2	653	6.81	67	1.45	1.89	7.34	7.55	33.24	0.20	0.67	9.34	1.87	5.3	12428	44247
				StDev		30%	3.22	3.6	216	0.7318	72	1.69	2.20	14.57	5.99	26.34	0.35	1.15	5.950172	2.72	3.353	34780.63	147577.9
				Median		68%	8.06	8.1	686	6.825	44	0.84	1.09	1.18	7.25	31.90	0.10	0.33	8.16	0.71	4.25	272	607

Table A-2. Wetland #1 Inlet Data - October, 2000 - May, 2002

Date of sample	Time of field sample	Air Temp. °C	Stream Flow Condition	Stream Flow (l/min)	Weather Pro ceeding	Weather During	Dissolved Oxygen (%Sat.)	Dissolved Oxygen (mg/l)	Water Temp. °C	Cond uctivity (µS)	pH	Tur bidity (FTU)	Ammonia Nitrogen (mg/l)	Total Ammonia (mg/l)	Un-ionized Ammonia (mg/l)	Nitrate Nitrogen (mg/l)	Nitrate (mg/l)	Nitrite Nitrogen (mg/l)	Nitrite (mg/l)	Total Nitrogen (mg/l)	Phos phate (mg/l)	Potassium (mg/l)	Fecal Coliform (CFU/ 100ml)	Fecal Entero (CFU/ 100ml)
27-Oct-00	12:01	n/s	low	60	dry	cloudy	10%	1.15	9.7	595	7.15	81	1.23	1.60	4.04	n/s	n/s	n/s	n/s	n/s	1.20	n/s	2600	n/s
16-Nov-00	10:40	6.1	med	120	dry	frost	20%	2.53	4.4	796	7.04	45	2.21	2.87	3.69	5.30	23.32	0.21	0.693	7.72	2.67	n/s	43	7040
28-Nov-00	10:30	6.0	low	150	dry	dry	19%	2.38	6.3	808	6.58	71	1.29	1.68	0.87	24.30	106.92	0.27	0.891	25.86	1.30	n/s	4400	27200
8-Dec-00	11:35	4.5	med	180	cloudy	cloudy	64%	8.03	5.6	861	6.69	35	0.37	0.48	0.30	15.00	66.00	0.51	1.683	15.88	0.89	n/s	12	96
15-Dec-00	10:20	2.1	v.high	300	sunny	sunny	61%	8.11	3.5	n/s	6.81	30	1.56	2.03	1.42	22.40	98.56	0.35	1.155	24.31	0.40	n/s	6600	36400
5-Jan-01	10:00	8.8	med	120	cloudy	cloudy	70%	8.70	6.0	730	6.41	57	0.41	0.53	0.18	20.60	90.64	0.98	3.234	21.99	0.49	n/s	247	3600
10-Jan-01	10:45	8.0	low	100	sunny	sunny	74%	9.35	5.6	689	6.60	51	0.79	1.03	0.53	15.20	66.88	0.26	0.858	16.25	n/s	n/s	33	60
24-Jan-01	10:00	5.0	med	180	l rain	l rain	80%	10.19	5.2	635	6.58	75	1.32	1.72	0.82	14.40	63.36	0.03	0.10	15.75	0.68	n/s	555	799
7-Feb-01	13:00	4.5	med	180	clear	clear	89%	11.08	5.5	598	6.66	70	0.75	0.98	0.57	10.50	46.20	0.06	0.20	11.31	0.68	n/s	400	31
21-Feb-01	13:30	6.8	med	39	clear	clear	69%	8.70	5.2	571	6.58	47	0.19	0.25	0.12	8.60	37.84	0.05	0.165	8.84	0.41	n/s	112	34
9-Mar-01	9:30	6.7	med	60	l rain	clear	73%	9.25	5.2	620	n/s	31	0.6	0.78	n/s	13.10	57.64	0.06	0.20	13.76	0.34	n/s	2	2
16-Mar-01	10:45	6.3	med	100	rain	cloudy	99%	12.25	6.5	614	7.14	43	0.34	0.44	0.85	13.70	60.28	0.04	0.132	14.08	0.10	4.3	4800	15800
23-Mar-01	10:10	8.2	med	n/s	sunny	sunny	n/s	12.75	7.2	599	7.17	46	0.34	0.44	0.96	13.70	60.28	0.04	0.132	14.08	0.00	4.1	18	12
6-Apr-01	8:30	6.6	med	n/s	rain	sunny	94%	10.19	7.6	589	7.60	46	0.43	0.56	3.36	12.30	54.12	0.04	0.132	12.77	0.02	4.0	304	82
12-Apr-01	9:20	6.8	med	145	cloudy	cloudy	136%	16.07	8.1	607	8.84	50	0.24	0.31	30.72	8.60	37.84	0.06	0.20	8.90	0.06	4.5	38	28
18-Apr-01	9:30	14.5	med	198	rain	sunny	116%	12.75	11.2	650	8.22	67	0.91	1.18	38.27	4.00	17.60	0.11	0.363	5.02	1.01	6.2	600	7100
25-Apr-01	11:46	14.9	low	n/s	sunny	sunny	114%	12.24	12.11	726	8.11	33	0.48	0.62	16.91	5.20	22.88	0.14	0.462	5.82	4.10	5.7	100	45
11-May-01	10:00	14.1	low	n/s	sunny	sunny	93%	9.61	13.6	753	8.75	43	0.42	0.55	65.51	2.86	12.58	0.17	0.561	3.45	0.86	6.6	320	48
18-May-01	9:25	13.8	low	215	cloudy	sunny	59%	4.61	12.8	691	8.81	39	1.00	1.30	166.83	2.11	9.28	0.20	0.66	3.31	1.78	8.3	2800	11600
25-May-01	14:00	19.1	med	80	sunny	sunny	36%	3.40	18.2	750	7.36	22	1.97	2.56	19.96	2.70	11.88	0.31	1.023	4.98	1.84	7.6	106	688
30-May-01	10:50	10.7	low	89	cloudy	l rain	35%	3.51	15.9	779	7.12	25	1.81	2.35	8.92	6.50	28.60	0.27	0.891	8.58	1.83	6.1	9600	2150
13-Jul-01	15:00	25.0	low	n/s	sunny	sunny	n/s	2.70	19.0	917	6.78	24	0.64	0.83	1.82	10.40	45.76	0.22	0.726	11.26	0.72	5.3	82	58
26-Oct-01	9:55	9.7	high	65	raining	cloudy	34%	3.87	9.5	1075	5.63	287	8.20	10.66	0.80	n/r	n/r	0.05	0.165	8.25	7.40	n/s	94400	390400
1-Nov-01	11:35	9.7	low	n/s	l rain	l rain	34%	3.94	8.9	1010	6.06	301	8.00	10.40	2.01	n/r	n/r	0.00	0.00	8.00	23.00	42.0	204800	28800
7-Nov-01	9:20	8.1	low	226	sunny	cloudy	23%	2.75	8.0	n/s	6.13	221	9.20	11.96	2.53	0.19	0.84	0.05	0.165	9.44	3.80	49.0	54400	68800
16-Nov-01	9:00	10.1	low	100	h rain	sunny	27%	3.07	9.8	n/s	7.05	199	1.36	1.77	3.57	21.90	96.36	4.60	15.18	27.86	1.40	15.0	35200	243200
28-Nov-01	11:00	4.7	high	133	rain	snow	64%	7.77	0.7	n/s	4.89	88	1.37	1.78	0.02	19.30	84.92	1.20	3.96	21.87	0.70	7.0	20800	172800
5-Dec-01	10:25	5.1	high	268	rain	sunny	58%	7.18	6.2	667	6.41	90	0.91	1.18	0.41	2.73	12.01	1.00	3.30	4.64	1.40	8.0	6000	12400
19-Dec-01	9:45	4.7	med	345	rain	cloudy	61%	7.72	5.4	403	6.73	123	0.46	0.60	0.41	13.70	60.28	0.38	1.254	14.54	1.40	7.4	400	6000
3-Jan-02	10:15	6.4	high	222	rain	cloudy	58%	7.20	5.8	573	6.24	74	1.76	2.29	0.52	6.50	28.60	n/s	n/s	8.26	2.20	6.7	2200	23200
16-Jan-02	10:30	4.7	med	185	cloudy	cloudy	44%	5.63	5.3	816	7.27	81	0.61	0.79	1.86	4.70	20.68	0.10	0.33	5.41	0.38	6.2	18	1400
30-Jan-02	9:00	2.2	med	62	rain	cloudy	63%	8.04	2.2	480	7.28	98	0.41	0.53	0.99	7.50	33.00	0.05	0.165	7.96	0.64	5.4	196	248
13-Feb-02	10:00	4.3	med	214	sunny	cloudy	52%	6.73	4.4	456	5.88	64	0.61	0.79	0.07	5.50	24.20	0.05	0.165	6.16	0.64	4.4	24	183
1-Mar-02	9:30	7.0	low	107	sunny	sunny	55%	6.84	6.4	260	n/s	102	0.49	0.64	n/s	2.76	12.14	0.03	0.10	3.28	0.62	4.5	20	60
14-Mar-02	13:25	6.5	med	n/s	rain	cloudy	78%	9.58	6.3	180	n/s	67	0.12	0.16	n/s	1.73	7.61	0.01	0.033	1.86	0.50	5.2	5600	59200
28-Mar-02	9:00	8.2	med	n/s	cloudy	cloudy	67%	8.36	6.4	220	8.00	81	0.5	0.65	8.83	1.85	8.14	0.02	0.066	2.37	0.50	6.0	400	4
4-Apr-02	9:20	8.8	low	68	sunny	sunny	89%	10.52	7.9	300	7.80	24	0.59	0.77	7.45	1.49	6.56	0.06	0.20	2.14	0.38	4.5	76	32
11-Apr-02	8:45	8.9	low	66	cloudy	cloudy	62%	9.35	8.9	n/s	7.70	25	0.64	0.83	6.95	1.77	7.79	0.04	0.132	2.45	0.44	3.9	20	2
19-Apr-02	9:30	11.2	med	n/s	sunny	sunny	99%	11.10	10.2	n/s	7.70	47	0.45	0.59	5.41	4.90	21.56	0.06	0.20	5.41	0.74	5.3	400	62
25-Apr-02	12:00	12.1	low	158	sunny	sunny	128%	14.28	11.5	n/s	8.30	31	0.05	0.07	2.57	2.85	12.54	0.05	0.165	2.95	0.40	4.7	76	42
9-May-02	10:05	18.2	low	49	cloudy	sunny	157%	15.84	14.0	n/s	9.50	42	0.27	0.35	154.97	0.43	1.89	0.04	0.132	0.74	0.48	6.0	4	400
			Mean	143			68%	8.03	8.1	637	7.15	75	1.35	1.75	14.89	8.72	38.36	0.31	1.03	9.94	1.71	8.8	11190	28003
			StDev	77			33%	3.80	4.0	208	0.97	65	2.10	2.73	37.19	6.86	30.17	0.76	2.50	7.04	3.71	10.4	35573	75518
			Median	126.5			64%	8.11	6.5	635	7.085	51	0.61	0.79	1.93	6.50	28.60	0.06	0.20	8.26	0.69	6.0	320	544

Table A-3. Wetland #1 Outlet Data - October, 2000 - May, 2002

Date of sample	Time of field sample	Air Temp. °C	Stream Flow Con dition	Weather Proceeding	Weather During	Dissolved Oxygen (%Sat.)	Dissolved Oxygen (mg/l)	Water Temp. °C	Conductivity (µS)	pH	Turb idity (FTU)	Ammonia Nitrogen (mg/l)	Total Amm onia (mg/l)	Un-ionized Ammonia (µg/l)	Nitrate Nitrogen (mg/l)	Nitrate (mg/l)	Nitrite Nitrogen (mg/l)	Nitrite (mg/l)	Total Nitrogen (mg/l)	Phosphate (mg/l)	Potassium (mg/l)	Fecal Coliform (CFU/ 100ml)	Fecal Entero (CFU/ 100ml)
27-Oct-00	12:15	n/s	low	dry	cloudy	11%	1.27	10.1	651	6.80	40	0.70	0.91	1.06	n/s	n/s	n/s	n/s	n/s	0.81	n/s	233	n/s
16-Nov-00	10:55	5.3	low	dry	dry	11%	1.43	4.2	768	6.79	23	2.01	2.61	1.86	4.10	18.04	0.14	0.46	6.25	2.23	n/s	2	4
28-Nov-00	10:30	6.0	low	dry	dry	17%	2.16	5.4	773	6.59	38	0.61	0.79	0.39	23.20	102.08	0.17	0.56	23.98	1.19	n/s	600	2600
8-Dec-00	12:00	n/s	low	cloudy	dry	9%	1.13	5.4	799	6.28	19	0.29	0.38	0.09	13.20	58.08	0.21	0.69	13.7	0.85	n/s	2	6
15-Dec-00	11:00	1.3	med	sunny	sunny	70%	9.50	2.8	n/s	6.99	25	1.40	1.82	1.83	16.10	70.84	0.31	1.02	17.81	0.50	n/s	1600	9600
5-Jan-01	11:00	8.8	med	cloudy	cloudy	49%	6.03	6.4	685	6.69	38	0.40	0.52	0.35	19.50	85.80	0.02	0.07	19.92	0.52	n/s	0	12
10-Jan-01	11:00	8.0	low	sunny	sunny	11%	1.40	5.5	666	6.47	31	0.30	0.39	0.15	13.30	58.52	0.03	0.10	13.63	n/s	n/s	0	0
24-Jan-01	10:15	5.0	med	l rain	l rain	56%	7.16	4.9	611	6.74	47	0.40	0.52	0.35	12.30	54.12	0.01	0.03	12.71	0.61	n/s	45	34
7-Feb-01	13:14	4.5	high	clear	clear	88%	11.33	4.3	589	6.89	53	0.50	0.65	0.59	10.80	47.52	0.00	0.00	11.30	0.61	n/s	6	2
21-Feb-01	14:00	6.8	low	clear	clear	38%	5.05	3.7	567	6.29	38	0.00	0.00	0.01	7.20	31.68	0.00	0.00	7.20	0.32	n/s	10	4
9-Mar-01	9:45	6.7	low	l rain	sunny	42%	5.19	6.4	552	n/s	27	0.12	0.16	n/s	9.40	41.36	0.01	0.03	9.53	0.48	n/s	0	0
16-Mar-01	11:10	5.6	med	rain	cloudy	42%	5.24	5.8	574	6.74	30	0.07	0.09	0.07	10.90	47.96	0.00	0.00	10.97	0.26	4.1	286	1000
23-Mar-01	10:50	8.8	med	sunny	sunny	15%	1.88	6.1	587	6.52	25	0.15	0.20	0.09	14.00	61.60	0.00	0.00	14.15	0.60	3.3	4	2
6-Apr-01	9:20	6.4	low	rain	sunny	13%	1.55	7.2	578	6.59	24	0.10	0.13	0.07	7.50	33.00	0.01	0.03	7.61	0.38	12.0	6	0
12-Apr-01	9:50	6.6	med	cloudy	cloudy	48%	5.76	7.3	658	7.03	34	0.07	0.09	0.14	9.00	39.60	0.00	0.00	9.07	0.06	4.3	4	24
18-Apr-01	9:20	14.5	med	rain	sunny	63%	6.93	10.6	639	7.16	33	0.23	0.30	0.83	2.50	33.00	0.03	0.10	2.76	0.30	5.0	8	216
25-Apr-01	12:15	14.6	low	sunny	sunny	10%	4.10	11.2	696	6.59	11	0.29	0.38	0.30	5.20	22.88	0.03	0.10	5.52	2.80	6.2	0	0
11-May-01	10:40	12.8	Low	sunny	sunny	16%	1.72	11.8	748	6.84	18	0.15	0.20	0.28	1.27	5.59	0.01	0.03	1.43	0.47	6.8	75	176
18-May-01	9:45	12.3	low	cloudy	sunny	8%	0.81	11.7	705	6.68	21	0.39	0.51	0.51	1.52	6.69	0.01	0.03	1.92	1.17	5.4	8	64
25-May-01	14:20	16.6	med	sunny	sunny	8%	0.75	15.5	748	6.78	17	0.53	0.69	1.16	1.24	5.46	0.04	0.13	1.81	1.23	7.0	0	256
30-May-01	11:08	10.7	low	cloudy	l rain	7%	0.71	14.2	776	6.72	20	0.61	0.79	1.05	1.66	7.30	0.05	0.17	2.32	1.34	5.7	2	16
13-Jul-01	15:30	21.0	low	sunny	sunny	n/s	0.90	17.0	899	6.44	20	0.61	0.79	0.68	6.20	27.28	0.05	0.17	6.86	0.51	5.5	0	6
26-Oct-01	10:20	10.0	med	rain	cloudy	10%	1.14	9.8	1051	6.10	123	2.00	2.60	0.59	0.20	0.88	n/s	n/s	n/s	4.90	n/s	486400	377600
1-Nov-01	12:00	10.1	low	l rain	l rain	29%	2.84	9.5	1010	6.20	137	12.20	15.86	4.43	n/s	n/s	n/s	n/s	n/s	1.80	44.0	16000	72000
7-Nov-01	9:52	8.3	low	sunny	cloudy	27%	2.19	8.2	n/s	6.43	108	8.30	10.79	4.62	0.34	1.50	0.07	0.23	8.71	3.10	28.0	8800	12000
16-Nov-01	9:36	9.9	low	h rain	sunny	20%	2.22	9.7	n/s	7.05	61	2.26	2.94	5.89	17.50	77.00	3.30	10.89	23.06	0.50	14.0	800	4200
28-Nov-01	11:45	4.2	high	rain	snow	33%	4.15	5.7	n/s	4.07	65	0.63	0.82	0.01	18.60	81.84	0.35	1.16	19.58	0.60	6.0	1200	9800
5-Dec-01	11:30	5.5	high	rain	sunny	34%	4.24	5.6	631	6.54	48	0.41	0.53	0.24	1.65	7.26	0.07	0.23	2.13	1.20	7.9	1200	1000
19-Dec-01	10:30	4.6	med	rain	cloudy	44%	5.46	5.0	407	6.93	86	0.50	0.65	0.68	0.72	3.17	0.05	0.17	1.27	1.10	6.4	14	233
3-Jan-02	10:45	6.2	high	rain	cloudy	36%	4.42	6.4	593	7.01	42	1.02	1.33	1.87	0.37	1.63	n/s	n/s	1.39	1.00	5.5	0	120
16-Jan-02	11:00	4.8	med	cloudy	cloudy	45%	5.75	4.9	848	7.22	45	0.20	0.26	0.53	5.40	23.76	0.04	0.13	5.64	0.36	5.5	6	582
30-Jan-02	9:40	2.2	med	snow/rain	cloudy	48%	6.64	2.6	568	7.09	75	0.02	0.03	0.03	4.20	18.48	0.02	0.07	4.24	0.54	4.2	18	1790
13-Feb-02	10:45	4.1	med	sunny	cloudy	80%	10.60	4.5	298	6.10	27	0.09	0.12	0.02	3.10	13.64	0.03	0.10	3.22	0.14	2.8	28	0
1-Mar-02	10:10	7.2	low	sunny	sunny	55%	6.90	5.1	240	n/s	46	0.06	0.08	n/s	2.30	10.12	0.01	0.03	2.40	0.54	4.0	0	2
14-Mar-02	13:25	6.4	low	rain	cloudy	54%	6.80	6.8	170	n/s	42	0.09	0.12	n/s	1.20	5.28	0.00	0.00	1.29	0.59	4.5	400	3000
28-Mar-02	9:00	8.3	low	cloudy	cloudy	48%	5.80	6.9	220	7.40	40	0.06	0.08	0.28	1.14	5.02	0.01	0.03	1.21	0.66	4.5	0	0
4-Apr-02	9:30	8.6	low	sunny	sunny	53%	6.50	7.7	230	7.60	20	0.19	0.25	1.49	0.49	2.16	0.01	0.03	0.69	0.21	7.9	8	0
11-Apr-02	8:45	8.6	low	cloudy	cloudy	45%	5.22	9.1	n/s	7.30	15	0.32	0.42	1.41	0.32	1.41	0.05	0.17	0.69	0.36	5.9	4	2
19-Apr-02	9:30	11.0	low	sunny	sunny	52%	5.87	10.5	n/s	7.60	34	0.45	0.59	4.41	4.10	18.04	0.03	0.10	4.58	0.53	7.0	62	184
25-Apr-02	12:00	12.0	low	sunny	sunny	71%	7.59	12.2	n/s	8.20	24	0.03	0.04	1.30	0.06	0.26	0.01	0.03	0.10	0.11	2.6	62	1
9-May-02	10:30	16.8	low	sunny	sunny	81%	8.44	13.2	n/s	8.70	22	0.32	0.42	43.86	0.23	1.01	0.01	0.03	0.56	0.08	2.8	14	14
				Mean		37%	4.51	7.83	622	6.79	41	0.95	1.24	2.20	6.46	29.00	0.14	0.46	7.40	0.89	7.9	12632	12414
				StDev		23%	2.86	3.49	213	0.70	28	2.24	2.91	7.09	6.48	28.37	0.54	1.78	6.78	0.94	8.4	75892	60335
				Median		40%	5.05	6.80	639	6.76	34	0.32	0.42	0.56	4.10	18.48	0.03	0.10	5.58	0.57	5.5	8	29

Table A-4. Wetland #2 Inlet Data - October, 2001 - May, 2002

Date of Sample	Time of field sample	Air Temp. C°	Stream Condition	Stream Flow (L/min)	Weather Proceed ing	Weather During	Dissolved Oxygen (%Sat.)	Dissolved Oxygen (mg/L)	Water Temp. °C	Conductivity (µS)	pH	Turb idity (FTU)	Total Ammonia Nitrogen (mg/L)	Total Ammonia (mg/l)	Un-ionized Ammonia (µg/l)	Nitrate Nitrogen (mg/l)	Nitrate (mg/l)	Nitrite Nitrogen (mg/l)	Nitrite (mg/l)	Total Nitrogen	Phosphate (mg/l)	Potas sium (mg/l)	Fecal Coliform Bacteria (CFU/100 ml)	Fecal Entero (CFU/100ml)
26-Oct-01	10:45	10.0	low	65	rain	cloudy	n/s	n/s	9.5	1031	5.69	269	7.60	9.88	0.85	n/s	n/s	n/s	n/s	n/s	2.70	n/s	72000	217600
2-Nov-01	9:30	8.1	low	39	l. rain	sunny	54%	6.20	9.1	965	6.39	166	12.50	16.25	6.81	NR	n/s	n/s	n/s	n/s	n/s	35.0	600	41600
6-Nov-01	11:20	8.7	low	38	rain	sunny	27%	3.00	8.3	n/s	6.42	174	3.40	4.42	1.86	0.99	4.36	0.40	1.32	4.79	3.50	49.0	37600	25600
16-Nov-01	10:05	10.2	low	125	h.rain	sunny	42%	4.50	10.2	n/s	7.36	136	1.33	1.73	7.35	1.27	5.59	6.80	22.44	9.4	1.70	6.6	33600	212800
29-Nov-01	9:45	5.5	high	229	rain	rain	64%	7.82	6.9	748	6.44	84	1.22	1.59	0.63	1.60	7.04	1.70	5.61	4.52	1.40	4.6	9600	179200
6-Dec-01	9:00	6.4	high	405	rain	cloudy	63%	7.10	6.4	610	6.10	150	1.00	1.30	0.23	2.66	11.70	2.00	6.60	5.66	6.50	5.2	6400	40000
20-Dec-01	10:20	5.2	med	344	cloudy	cloudy	55%	7.05	4.9	420	7.38	84	0.32	0.42	1.21	10.70	47.08	0.31	1.02	11.33	2.40	5.4	400	2000
3-Jan-02	9:20	6.5	high	369	rain	cloudy	67%	8.36	6.0	575	6.63	108	1.38	1.79	1.02	5.00	22.00	0.20	0.66	6.58	1.60	7.4	5200	32800
16-Jan-02	9:30	4.8	med	292	cloudy	cloudy	49%	6.30	5.2	700	7.9	81	0.73	0.95	9.33	8.70	38.28	0.06	0.20	9.49	0.26	4.4	47	920
31-Jan-02	13:15	5.2	med	235	rain	cloudy	68%	8.68	5.3	530	7.65	108	0.35	0.46	2.55	9.30	40.92	0.05	0.17	9.7	0.60	5.3	200	147
14-Feb-02	10:30	6.5	low	66	sunny	sunny	50%	6.26	6.0	n/s	6.42	57	1.22	1.59	0.56	9.50	41.80	0.06	0.20	10.78	0.64	6.1	10	28
1-Mar-02	11:30	7.1	low	89	sunny	sunny	59%	7.81	5.7	270	n/s	81	0.54	0.70	n/s	2.77	12.19	0.04	0.13	3.35	0.56	4.6	13	60
15-Mar-02	9:00	6.6	med	85	rain	l.rain	72%	8.8	6.8	190	n/s	129	0.65	0.85	n/s	1.51	6.64	0.03	0.10	2.19	0.54	5.5	4800	10400
4-Apr-02	9:40	8.4	low	57	sunny	sunny	85%	9.79	8.2	290	7.90	20	0.39	0.51	6.33	2.40	10.56	0.06	0.20	2.85	0.36	7.2	60	40
11-Apr-02	9:55	9.6	low	146	cloudy	cloudy	66%	11.34	10.0	n/s	8.00	24	0.62	0.81	14.52	1.41	6.20	0.06	0.20	2.09	0.37	5.0	18	1
19-Apr-02	10:35	10.8	med	n/s	sunny	sunny	89%	9.93	11.2	n/s	7.70	42	0.46	0.60	5.98	7.00	30.80	0.01	0.03	7.47	0.68	3.2	200	25
25-Apr-02	12:55	11.6	low	n/s	sunny	sunny	98%	10.65	11.4	n/s	8.30	24	0.33	0.43	16.83	2.52	11.09	0.08	0.26	2.93	0.48	4.1	48	8
9-May-02	10:55	18.3	low	11	cloudy	sunny	118%	12.22	14.2	n/s	9.50	31	0.10	0.13	57.88	0.71	3.12	0.05	0.17	0.86	2.63	4.7	6	4
			Mean	162			66%	7.99	8.07	575	7.24	98	1.90	2.47	8.37	4.25	18.71	0.74	2.46	5.87	1.58	9.6	9489	42402
			StDev	129			18%	2.21	2.18	275	0.82	65	3.23	4.20	5.25	3.54	15.56	1.77	5.86	3.28	1.64	12.8	19676	77320
			Median	107			64%	7.82	7.55	575	7.37	84	0.69	0.90	4.26	2.59	11.40	0.06	0.20	5.23	0.68	5.3	300	1460

Table A-5. Wetland #2 Outlet Data - October, 2001 - May, 2002

Date of Sample	Time of field sample	Air Temp. C^0	Stream Condition	Stream Flow (L/min)	Weather Proceed ing	Weather During	Dissolved Oxygen (%Sat.)	Dissolved Oxygen (mg/L)	Water Temp. ^{0}C	Conductiv ity (µS)	pH	Turbidity (FTU)	Total Ammonia Nitrogen (mg/L)	Total Amm onia (mg/l)	Un-ionized Ammonia (µg/l)	Nitrate Nitrogen (mg/l)	Nitrate (mg/l)	Nitrite Nitrogen (mg/l)	Nitrite (mg/l)	Total Nitrogen	Phosphate (mg/l)	Potassium (mg/l)	Fecal Coliform Bacteria (CFU/100 ml)	Fecal Entero (CFU/100ml)
26-Oct-01	11:30	10.1	low	65	rain	cloudy	7%	0.75	9.9	1018	5.70	216	5.70	7.41	0.68	n/s	n/s	n/s	n/s	n/s	n/s	n/s	1549000	492800
2-Nov-01	9:50	8.9	low	39	sprinkle	sunny	54%	6.22	9.2	859	6.61	166	4.80	6.24	4.38	n/s	n/s	n/s	n/s	n/s	18.00	46.0	288	19200
6-Nov-01	11:40	8.9	n/s	38	rain	sunny	17%	2.10	8.5	n/s	6.65	135	3.90	5.07	3.69	0.61	2.68	0.27	0.89	4.78	3.00	40.0	3600	11200
16-Nov-01	10:20	9.8	low	125	h.rain	sunny	24%	2.40	10.6	n/s	7.22	95	1.07	1.39	4.42	1.32	5.81	5.00	16.50	7.39	1.00	1.4	9600	68800
29-Nov-01	10:30	6.6	high	229	rain	rain	37%	4.47	5.4	706	6.82	98	1.05	1.37	1.15	1.70	7.48	0.90	2.97	3.65	1.20	5.6	5200	36800
6-Dec-01	9:45	6.2	high	405	rain	cloudy	45%	5.46	6.3	623	6.15	194	0.65	0.85	0.16	1.25	5.50	0.65	2.15	2.55	4.90	4.6	1800	58000
20-Dec-01	11:50	5.5	med	344	cloudy	cloudy	44%	5.66	5.0	418	7.13	72	0.51	0.66	1.10	9.80	43.12	0.08	0.26	10.39	1.20	4.9	139	152
3-Jan-02	9:20	6.7	high	369	rain	cloudy	19%	2.32	5.8	754	7.30	76	0.38	0.49	1.29	3.50	15.40	0.10	0.33	3.98	1.40	5.8	800	2600
16-Jan-02	10:05	4.7	med	292	cloudy	cloudy	29%	3.61	5.3	670	7.48	56	0.07	0.09	0.35	5.90	25.96	0.03	0.10	6.00	0.43	4.0	0	445
31-Jan-02	14:00	5.3	med	235	rain	cloudy	59%	57.70	5.1	591	7.44	97	0.09	0.12	0.40	9.00	39.60	0.02	0.07	9.11	0.79	4.4	13	147
14-Feb-02	10:30	7.4	low	66	sunny	sunny	50%	6.26	6.0	n/s	6.42	57	1.22	1.59	0.56	5.90	25.96	0.04	0.13	7.16	0.26	3.1	2	10
1-Mar-02	11:45	7	low	89	sunny	sunny	48%	4.88	5.5	250	n/s	65	0.13	0.17	n/s	1.79	7.88	0.01	0.03	1.93	0.59	4.2	4	4
15-Mar-02	9:00	6.4	med	85	rain	l.rain	52%	6.35	6.3	190	n/s	77	0.25	0.33	n/s	1.51	6.64	0.01	0.03	1.77	0.69	5.0	18	800
4-Apr-02	9:50	8.3	low	57	sunny	sunny	59%	6.95	8.1	190	7.70	20	0.22	0.29	2.24	2.11	9.28	0.01	0.03	2.34	0.31	8.2	6	2
11-Apr-02	9:55	9.6	low	146.3	cloudy	cloudy	53%	6.34	9.7	n/s	7.40	22	0.27	0.35	1.57	1.73	7.61	0.02	0.07	2.02	0.44	8.5	60	40
19-Apr-02	10:35	10.6	med	n/s	sunny	sunny	62%	6.84	10.5	n/s	8.00	11	0.52	0.68	12.65	5.60	24.64	0.03	0.10	6.15	0.88	5.6	16	4
25-Apr-02	13:25	11.2	low	n/s	sunny	sunny	59%	6.36	11.2	n/s	8.10	15	0.41	0.53	13.18	2.29	10.08	0.02	0.07	2.72	1.00	4.0	2	2
9-May-02	11:30	16.9	low	11	cloudy	sunny	88%	8.73	13.5	n/s	8.00	14	0.09	0.12	2.75	0.31	1.36	0.02	0.07	0.42	0.51	7.4	0	277
					Mean		45%	7.97	7.88	570	7.13	83	1.19	1.54	3.16	3.40	14.94	0.45	1.49	4.52	2.15	9.6	87253	38405
					St.Dev		20%	12.58	2.59	276	0.69	62	1.73	2.24	4.06	2.95	12.99	1.24	4.09	2.90	4.24	12.7	364813	115366
					Median		49%	5.94	7.20	623	7.26	74	0.46	0.60	1.43	1.95	8.58	0.03	0.10	3.82	0.88	5.0	39	361

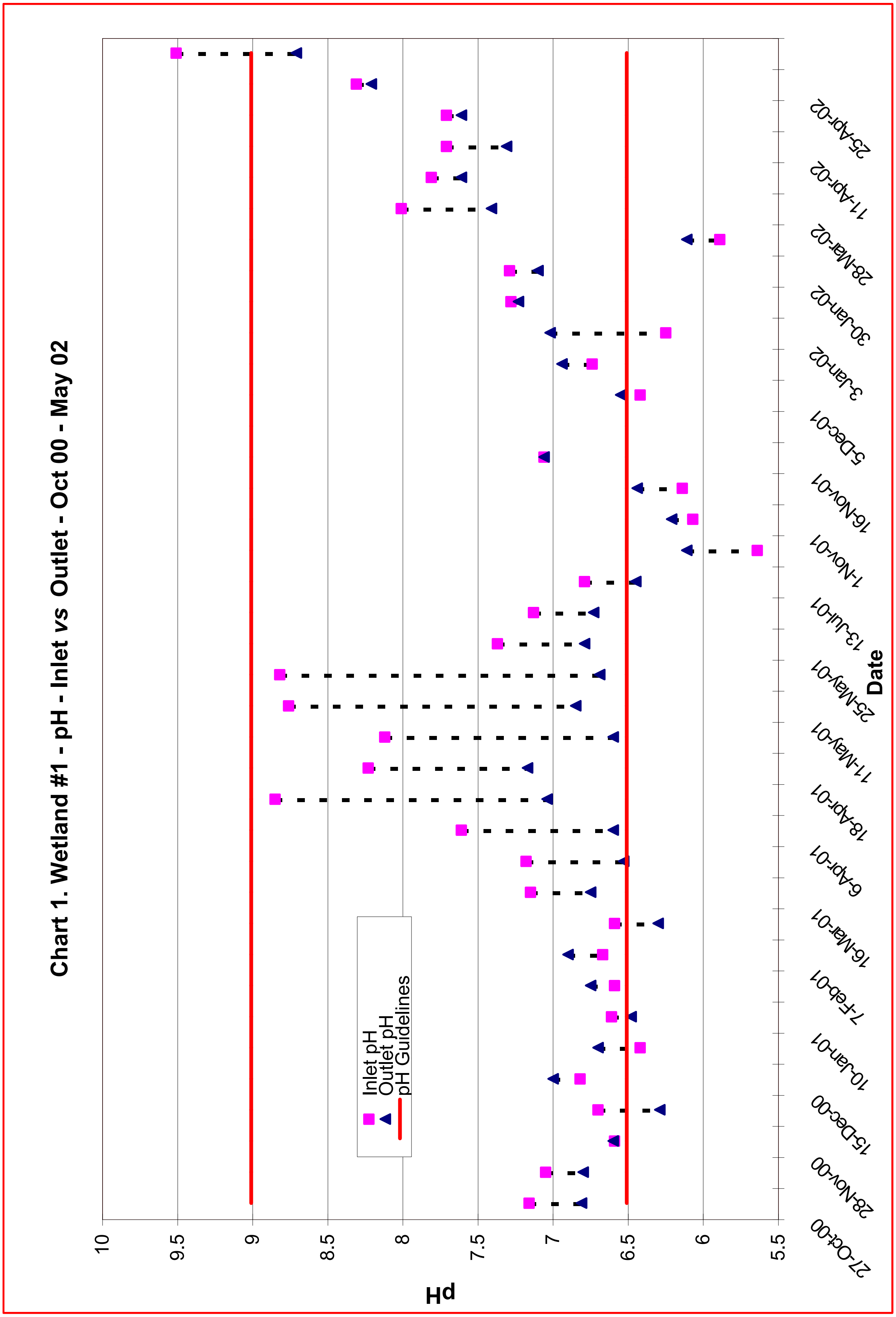
Chart 1. Wetland #1 - pH - Inlet *vs* Outlet - Oct 00 - May 02
Inlet pH
Outlet pH
pH Guidelines
pH
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
Date
27-Oct-00
28-Nov-00
15-Dec-00
10-Jan-01
7-Feb-01
16-Mar-01
6-Apr-01
18-Apr-01
11-May-01
25-May-01
13-Jul-01
1-Nov-01
16-Nov-01
5-Dec-01
3-Jan-02
30-Jan-02
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11-Apr-02
25-Apr-02

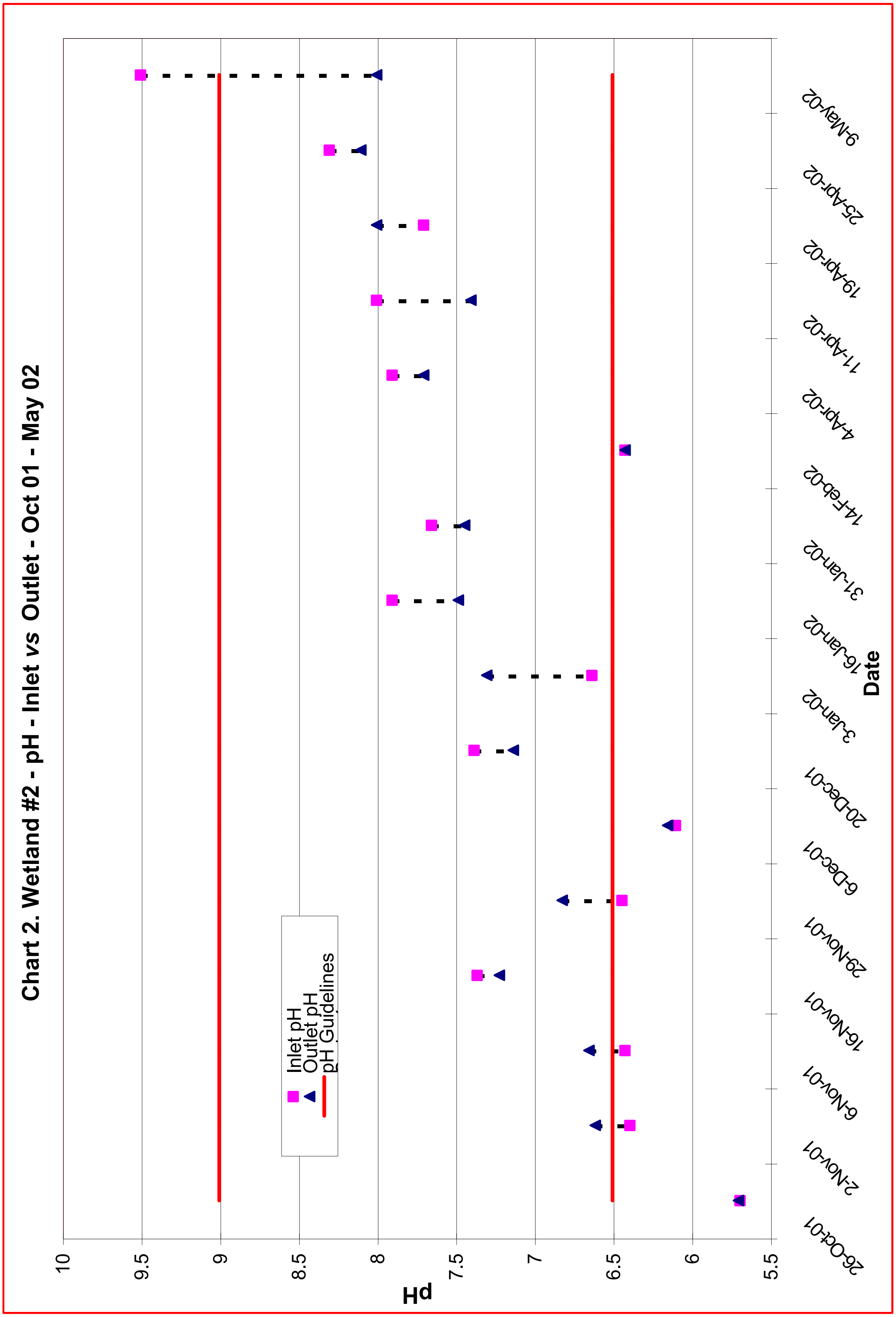
Chart 2. Wetland #2 - pH - Inlet *vs* Outlet - Oct 01 - May 02
pH
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
Inlet pH
Outlet pH
pH Guidelines
Date
26-Oct-01
2-Nov-01
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
14-Feb-02
4-Apr-02
11-Apr-02
19-Apr-02
25-Apr-02
9-May-02

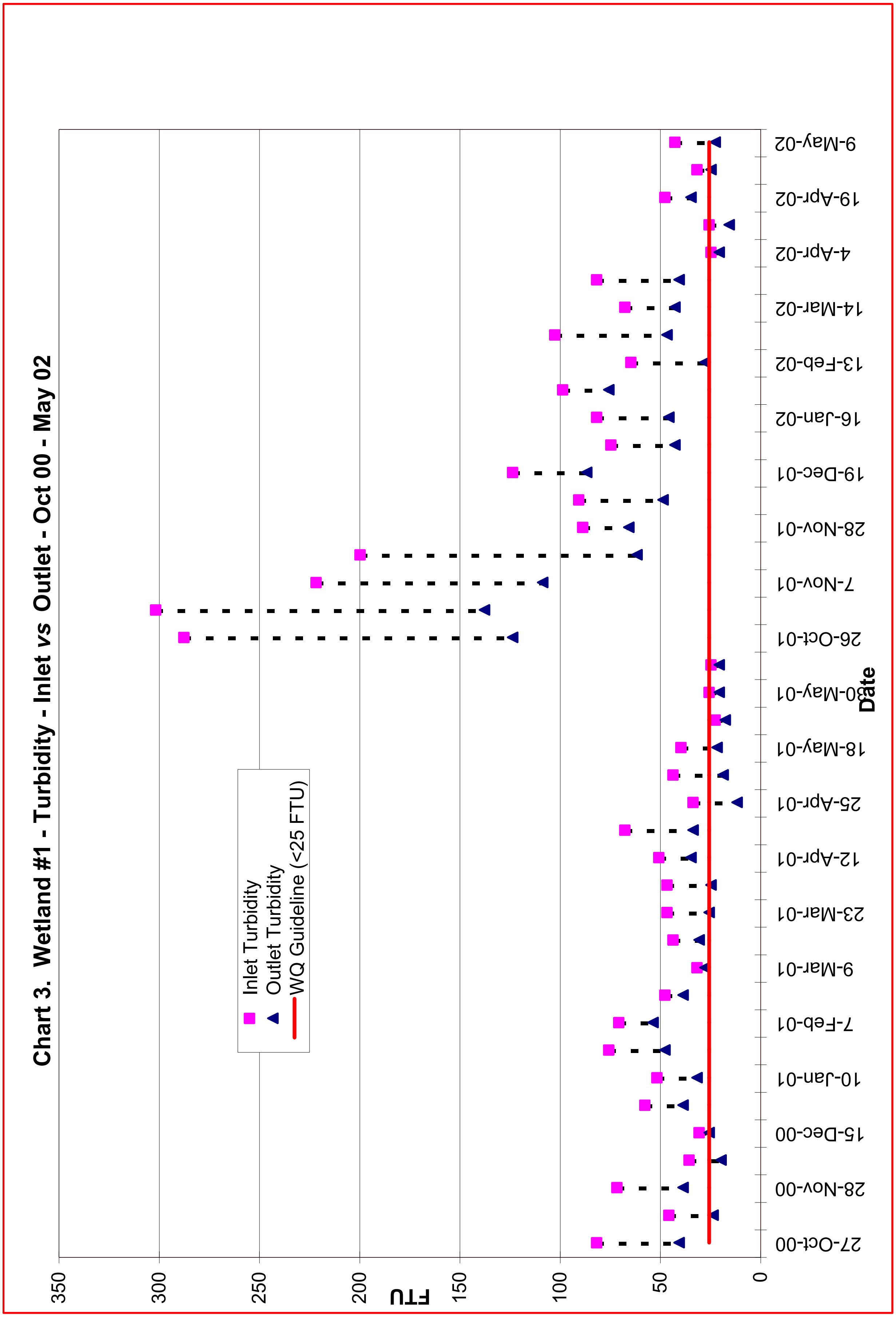
Chart 3. Wetland #1 - Turbidity - Inlet vs Outlet - Oct 00 - May 02
Inlet Turbidity
Outlet Turbidity
WQ Guideline (<25 FTU)
FTU
350
300
250
200
150
100
50
0
Date
27-Oct-00
28-Nov-00
15-Dec-00
10-Jan-01
7-Feb-01
9-Mar-01
23-Mar-01
12-Apr-01
25-Apr-01
18-May-01
30-May-01
26-Oct-01
7-Nov-01
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16-Jan-02
13-Feb-02
14-Mar-02
4-Apr-02
19-Apr-02
9-May-02

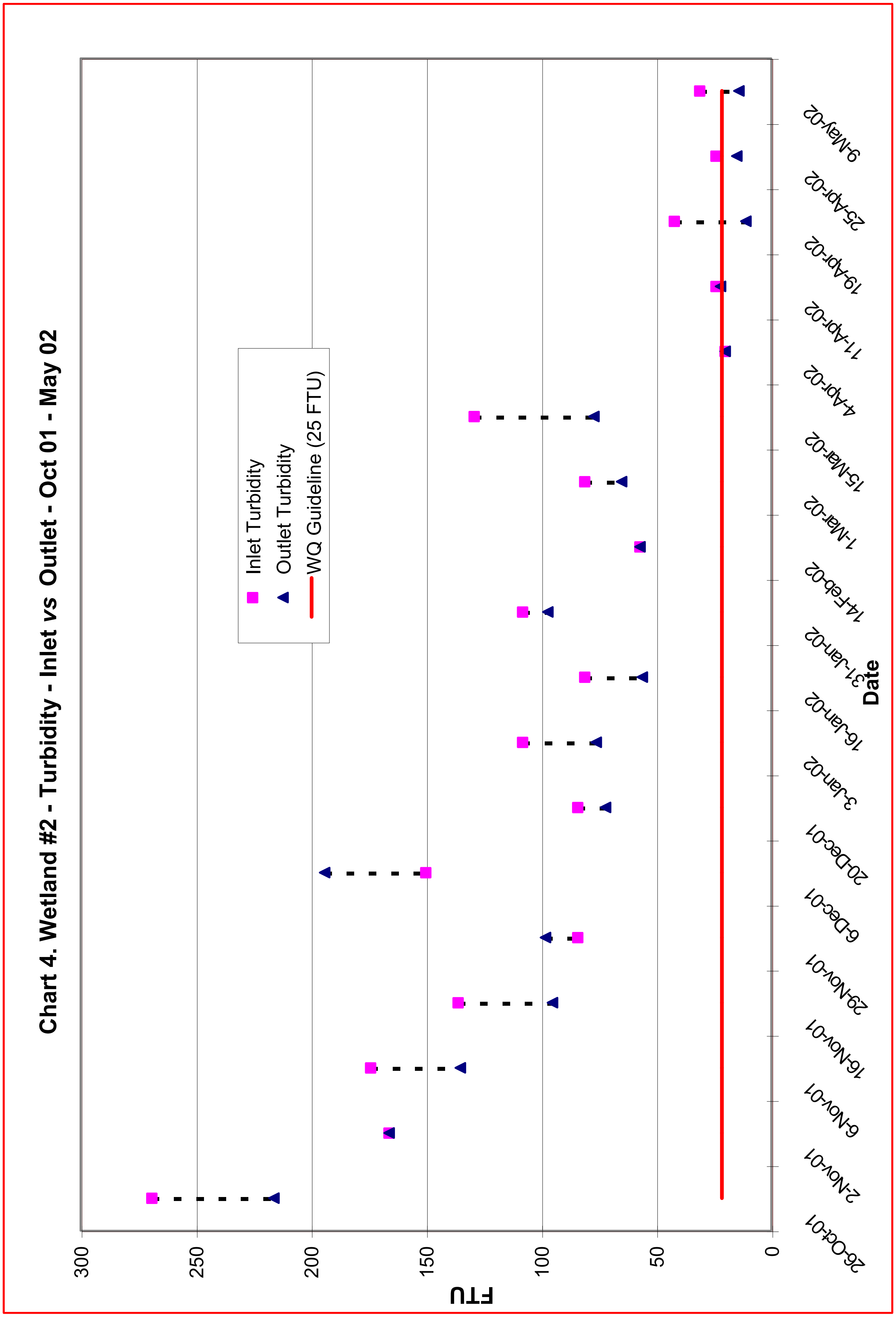
Chart 4. Wetland #2 - Turbidity - Inlet *vs* Outlet - Oct 01 - May 02
Inlet Turbidity
Outlet Turbidity
WQ Guideline (25 FTU)
FTU
300
250
200
150
100
50
0
Date
26-Oct-01
2-Nov-01
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
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1-Mar-02
15-Mar-02
4-Apr-02
11-Apr-02
19-Apr-02
25-Apr-02
9-May-02

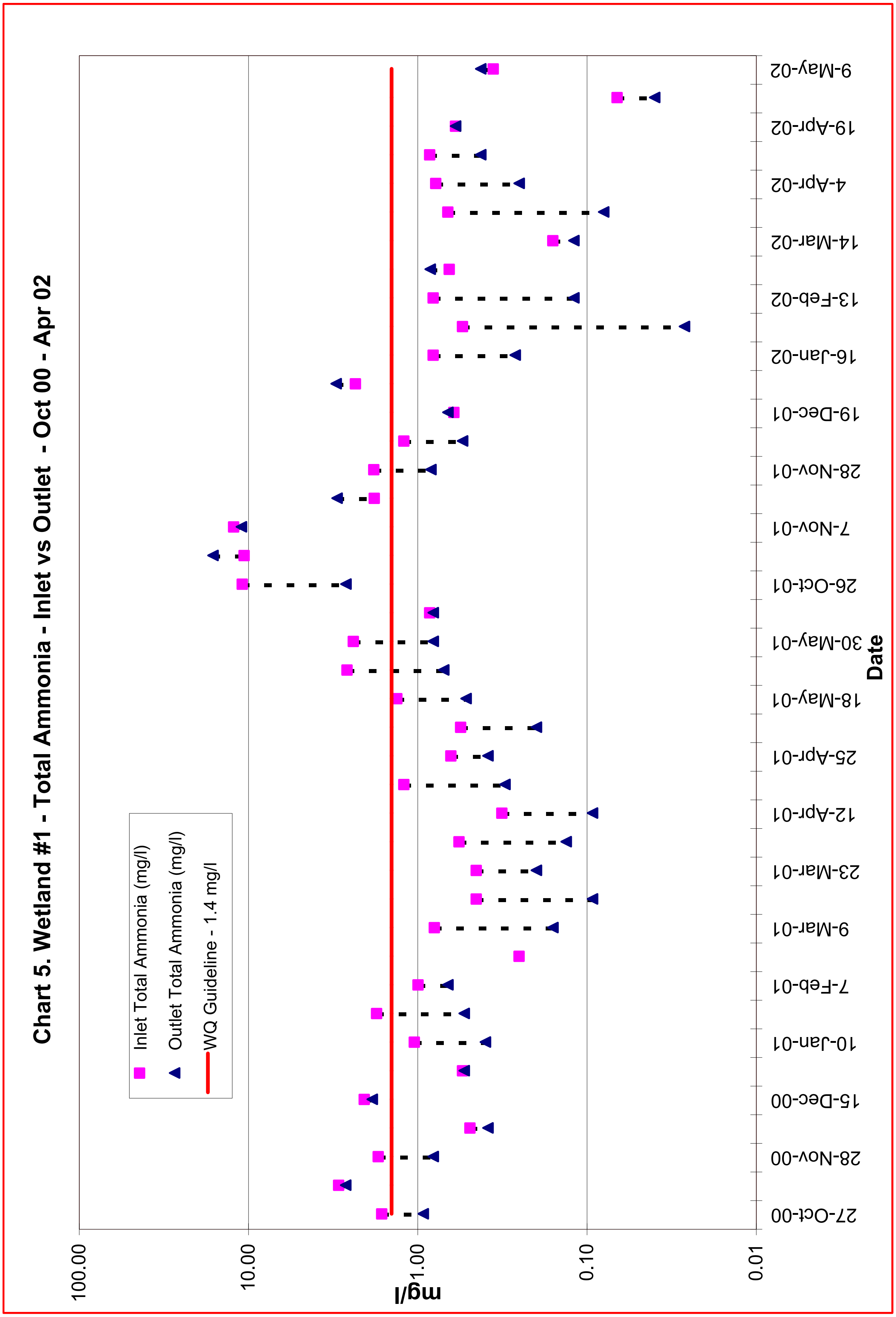
Chart 5. Wetland #1 - Total Ammonia - Inlet vs Outlet - Oct 00 - Apr 02
Inlet Total Ammonia (mg/l)
Outlet Total Ammonia (mg/l)
WQ Guideline - 1.4 mg/l
100.00
10.00
1.00
0.10
0.01
mg/l
27-Oct-00
28-Nov-00
15-Dec-00
10-Jan-01
7-Feb-01
9-Mar-01
23-Mar-01
12-Apr-01
25-Apr-01
18-May-01
30-May-01
26-Oct-01
7-Nov-01
28-Nov-01
19-Dec-01
16-Jan-02
13-Feb-02
14-Mar-02
4-Apr-02
19-Apr-02
9-May-02
Date

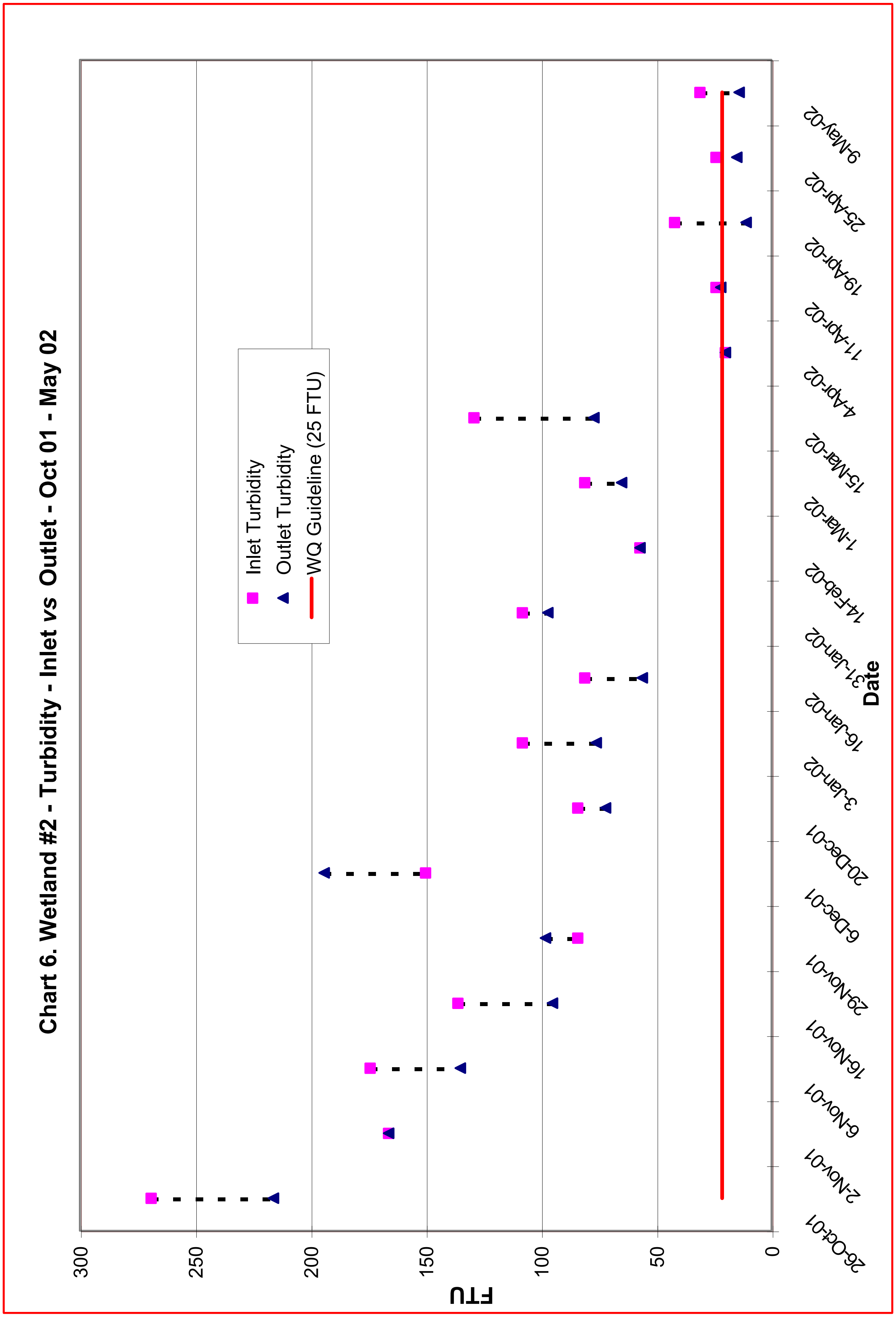
Chart 6. Wetland #2 - Turbidity - Inlet *vs* Outlet - Oct 01 - May 02
Inlet Turbidity
Outlet Turbidity
WQ Guideline (25 FTU)
FTU
300
250
200
150
100
50
0
Date
26-Oct-01
2-Nov-01
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
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1-Mar-02
15-Mar-02
4-Apr-02
11-Apr-02
19-Apr-02
25-Apr-02
9-May-02

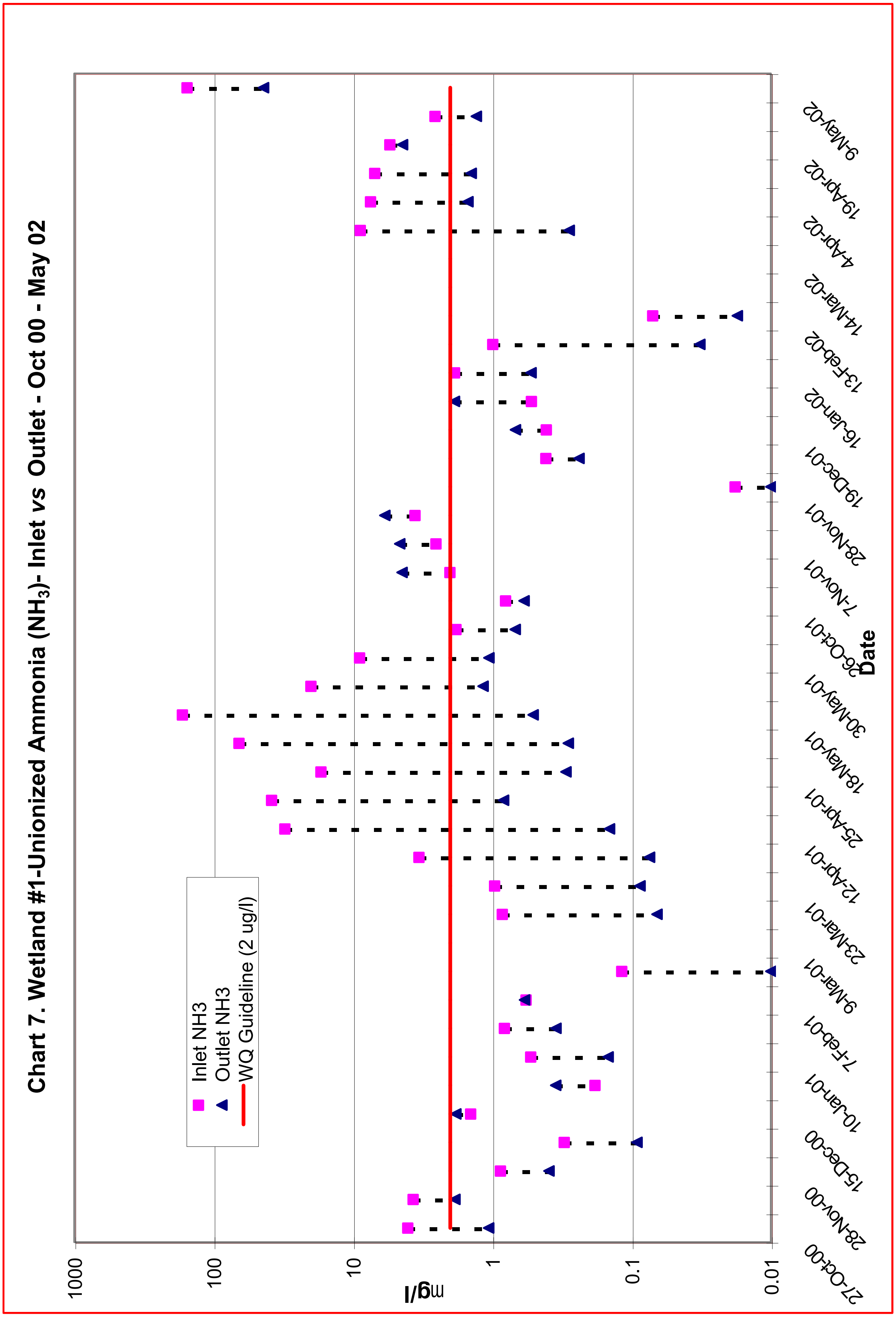
Chart 7. Wetland #1-Unionized Ammonia (NH_3)- Inlet *vs* Outlet - Oct 00 - May 02
Inlet NH3
Outlet NH3
WQ Guideline (2 ug/l)
mg/l
1000
100
10
1
0.1
0.01
Date
27-Oct-00
28-Nov-00
15-Dec-00
10-Jan-01
7-Feb-01
9-Mar-01
23-Mar-01
12-Apr-01
25-Apr-01
18-May-01
30-May-01
26-Oct-01
7-Nov-01
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16-Jan-02
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4-Apr-02
19-Apr-02
9-May-02

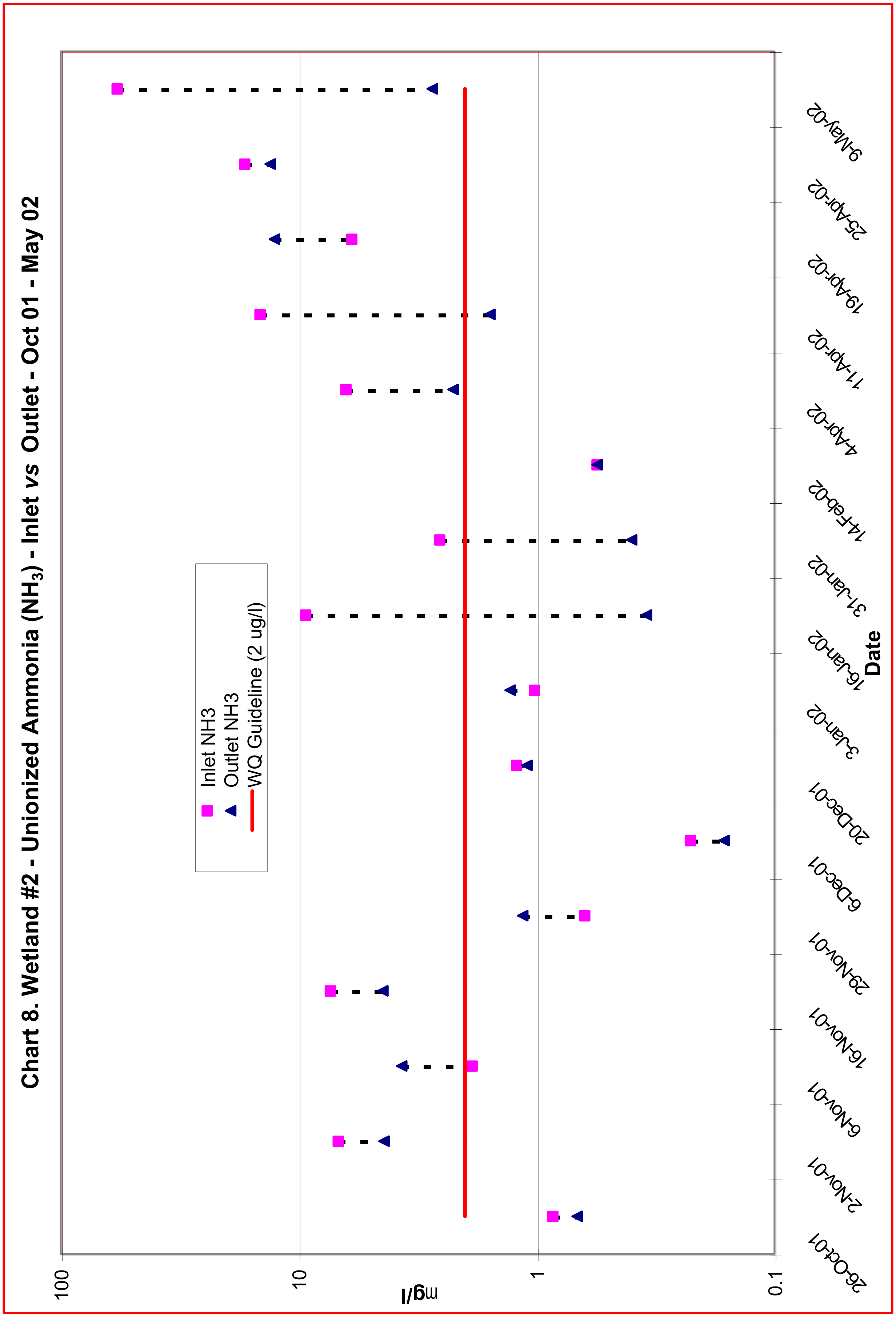


Chart 8. Wetland #2 - Unionized Ammonia (NH3) - Inlet vs Outlet - Oct 01 - May 02
Inlet NH3
Outlet NH3
WQ Guideline (2 ug/l)
mg/l
100
10
1
0.1
Date
26-Oct-01
2-Nov-01
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
14-Feb-02
4-Apr-02
11-Apr-02
19-Apr-02
25-Apr-02
9-May-02

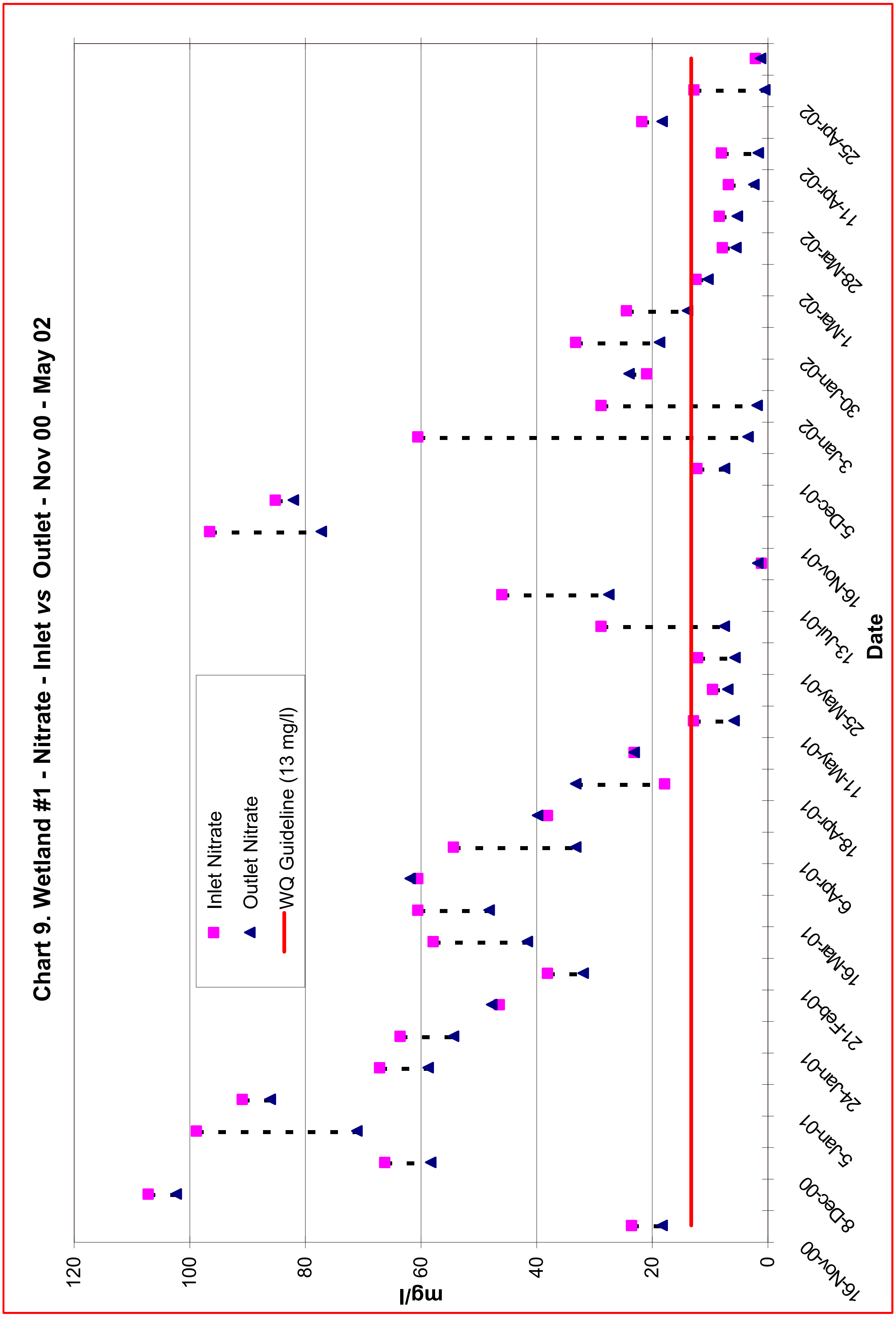


Chart 9. Wetland #1 - Nitrate - Inlet vs Outlet - Nov 00 - May 02
Inlet Nitrate
Outlet Nitrate
WQ Guideline (13 mg/l)
mg/l
Date
0
20
40
60
80
100
120
16-Nov-00
8-Dec-00
5-Jan-01
24-Jan-01
21-Feb-01
16-Mar-01
6-Apr-01
18-Apr-01
11-May-01
25-May-01
13-Jul-01
16-Nov-01
5-Dec-01
3-Jan-02
30-Jan-02
1-Mar-02
28-Mar-02
11-Apr-02
25-Apr-02

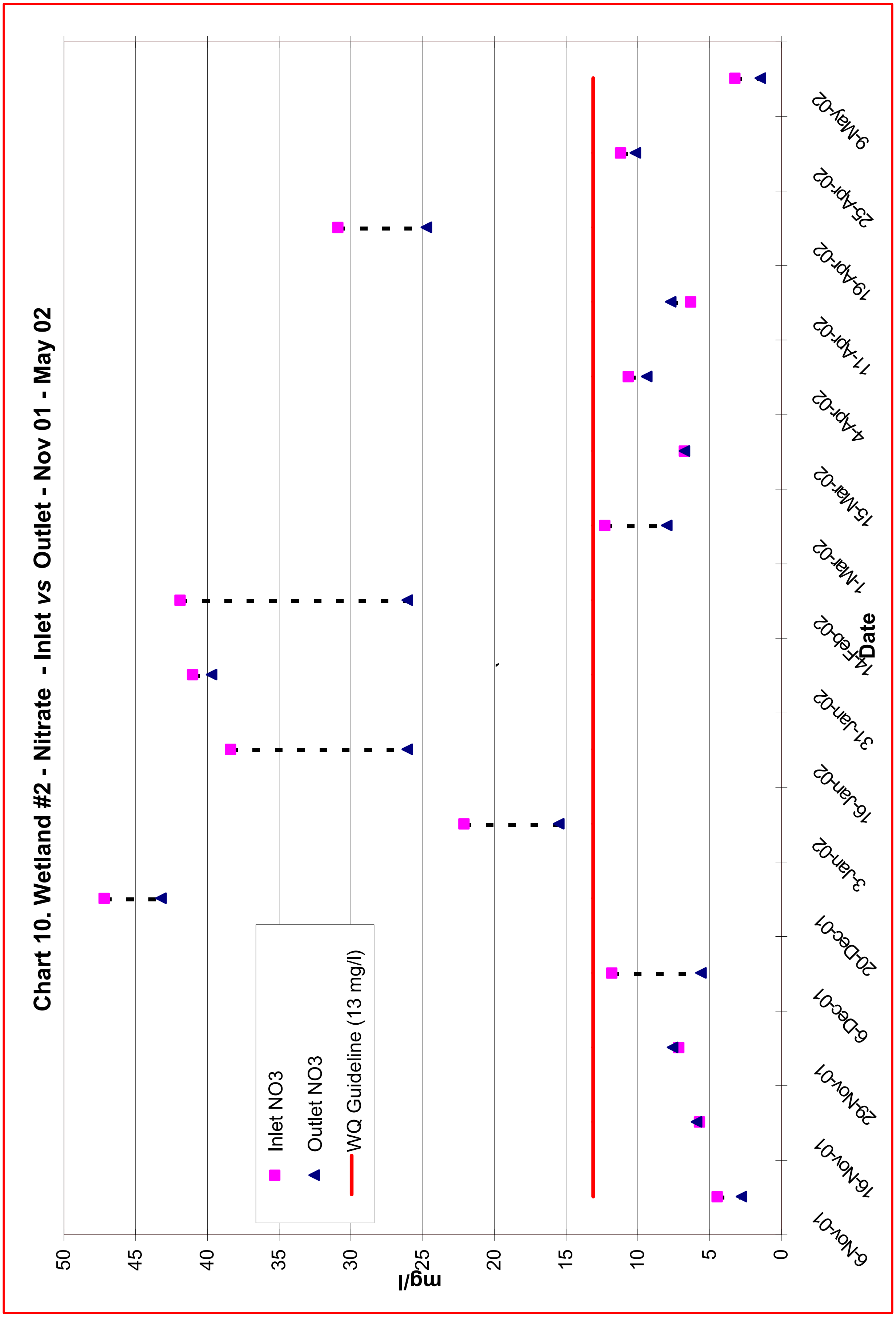
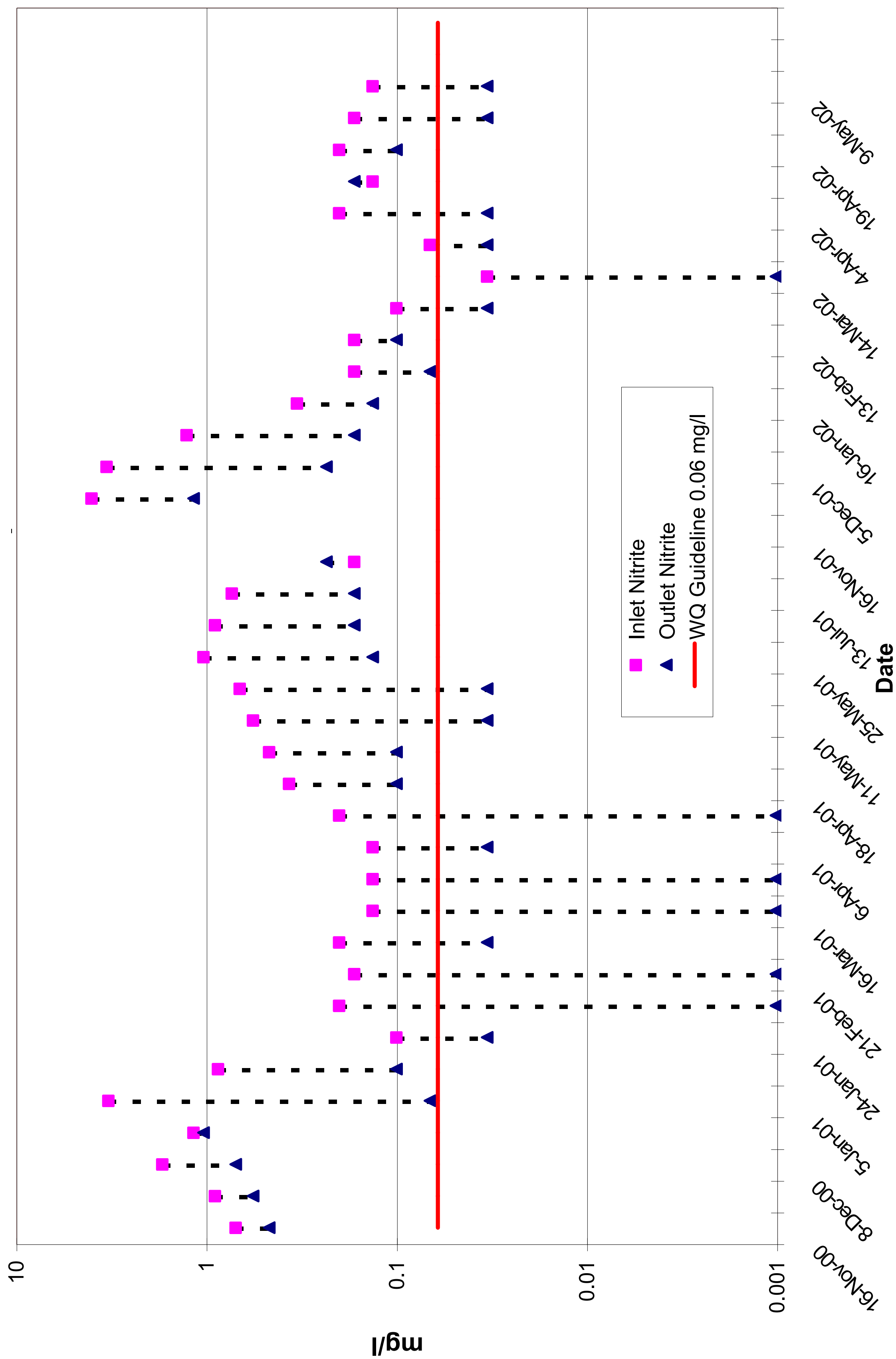


Chart 10. Wetland #2 - Nitrate - Inlet vs Outlet - Nov 01 - May 02
Inlet NO3
Outlet NO3
WQ Guideline (13 mg/l)
mg/l
50
45
40
35
30
25
20
15
10
5
0
Date
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
14-Feb-02
1-Mar-02
15-Mar-02
4-Apr-02
11-Apr-02
19-Apr-02
25-Apr-02
9-May-02

Chart 11. Wetland #1 - Nitrite (NO_2) - Inlet *vs* Outlet - Nov 00 - May 02



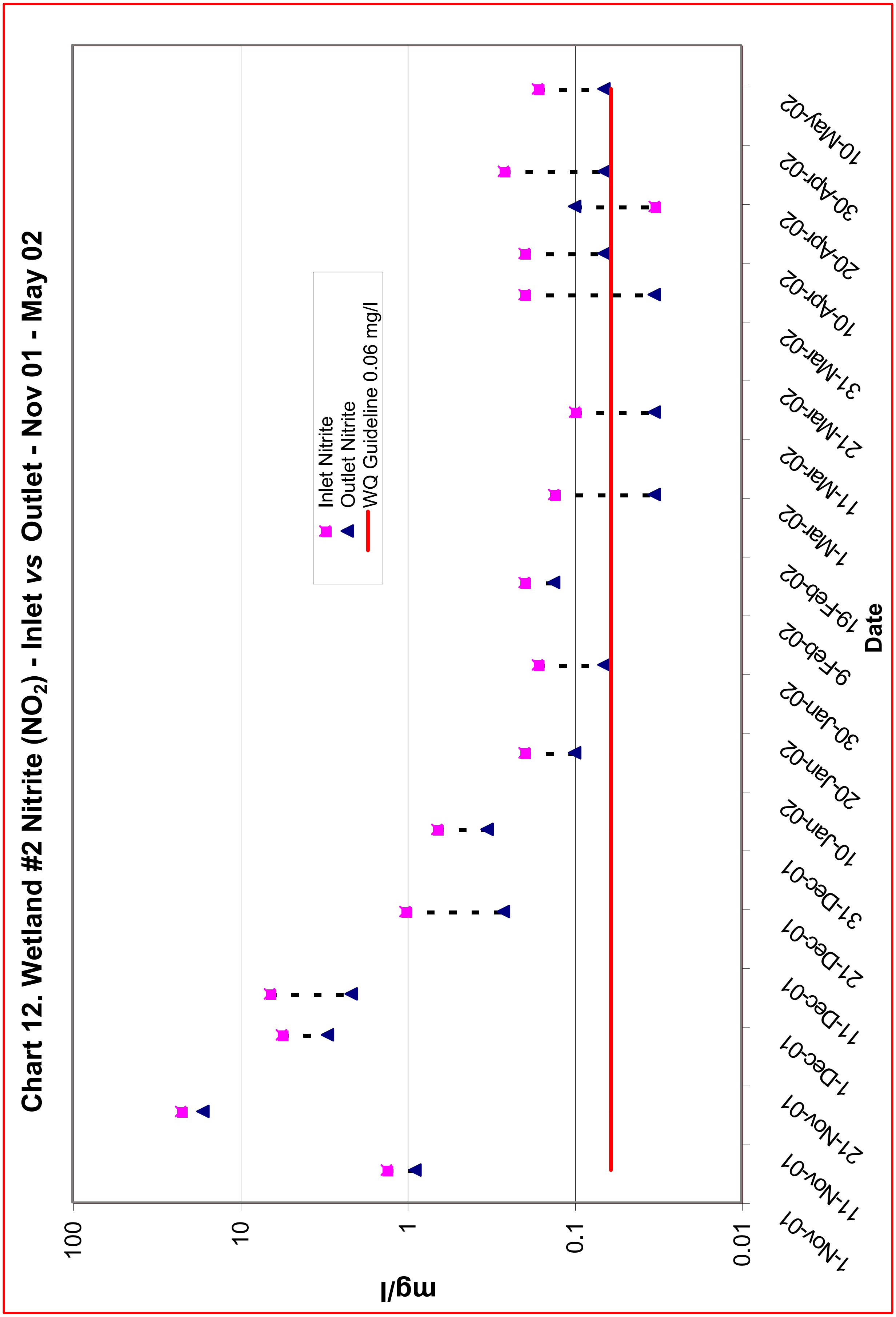


Chart 12. Wetland #2 Nitrite (NO2) - Inlet vs Outlet - Nov 01 - May 02
Inlet Nitrite
Outlet Nitrite
WQ Guideline 0.06 mg/l
mg/l
100
10
1
0.1
0.01
Date
1-Nov-01
11-Nov-01
21-Nov-01
1-Dec-01
11-Dec-01
21-Dec-01
31-Dec-01
10-Jan-02
20-Jan-02
30-Jan-02
9-Feb-02
19-Feb-02
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20-Apr-02
30-Apr-02
10-May-02

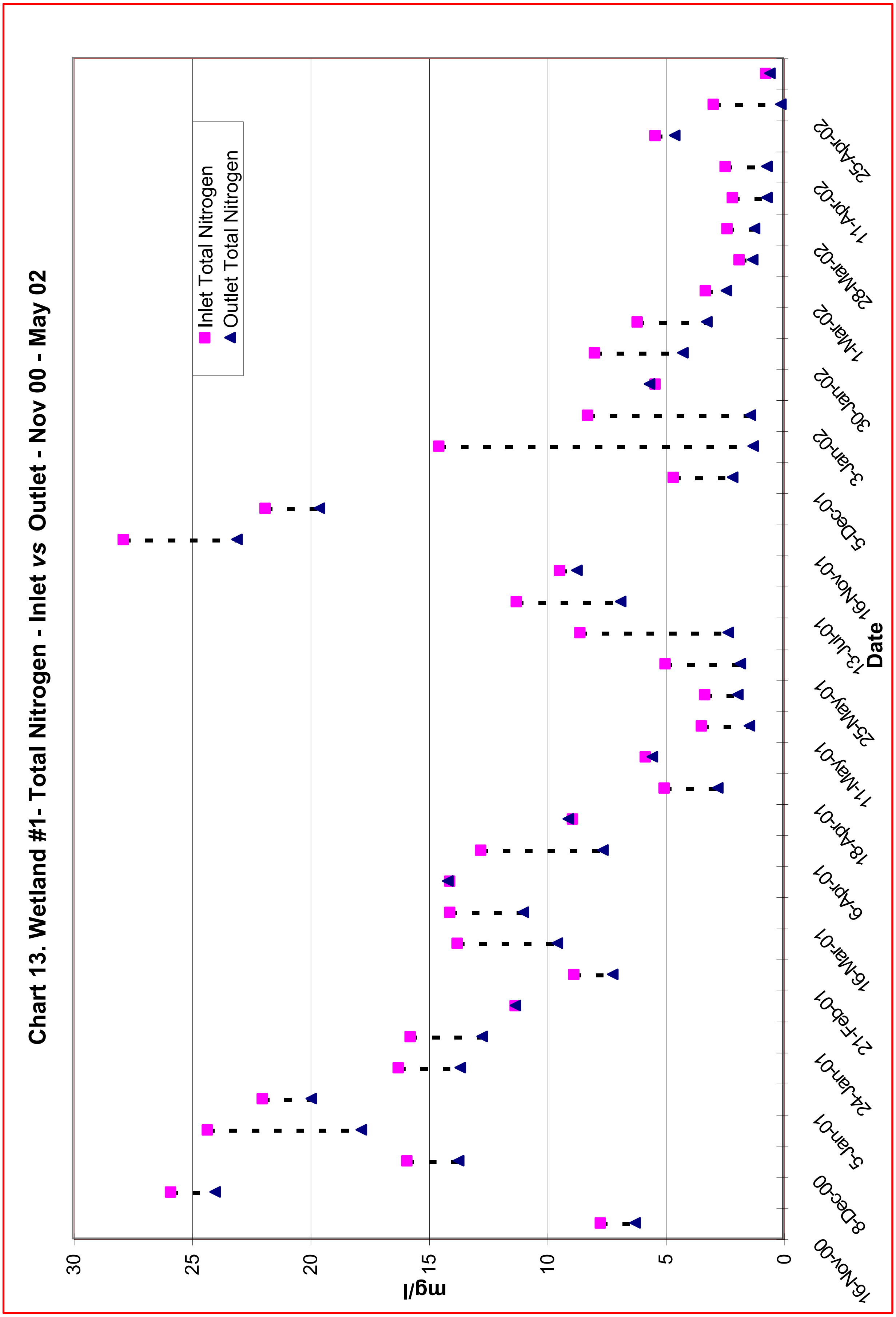
Chart 13. Wetland #1- Total Nitrogen - Inlet *vs* Outlet - Nov 00 - May 02
Inlet Total Nitrogen
Outlet Total Nitrogen
mg/l
0
5
10
15
20
25
30
Date
16-Nov-00
8-Dec-00
5-Jan-01
24-Jan-01
21-Feb-01
16-Mar-01
6-Apr-01
18-Apr-01
11-May-01
25-May-01
13-Jul-01
16-Nov-01
5-Dec-01
3-Jan-02
30-Jan-02
1-Mar-02
28-Mar-02
11-Apr-02
25-Apr-02

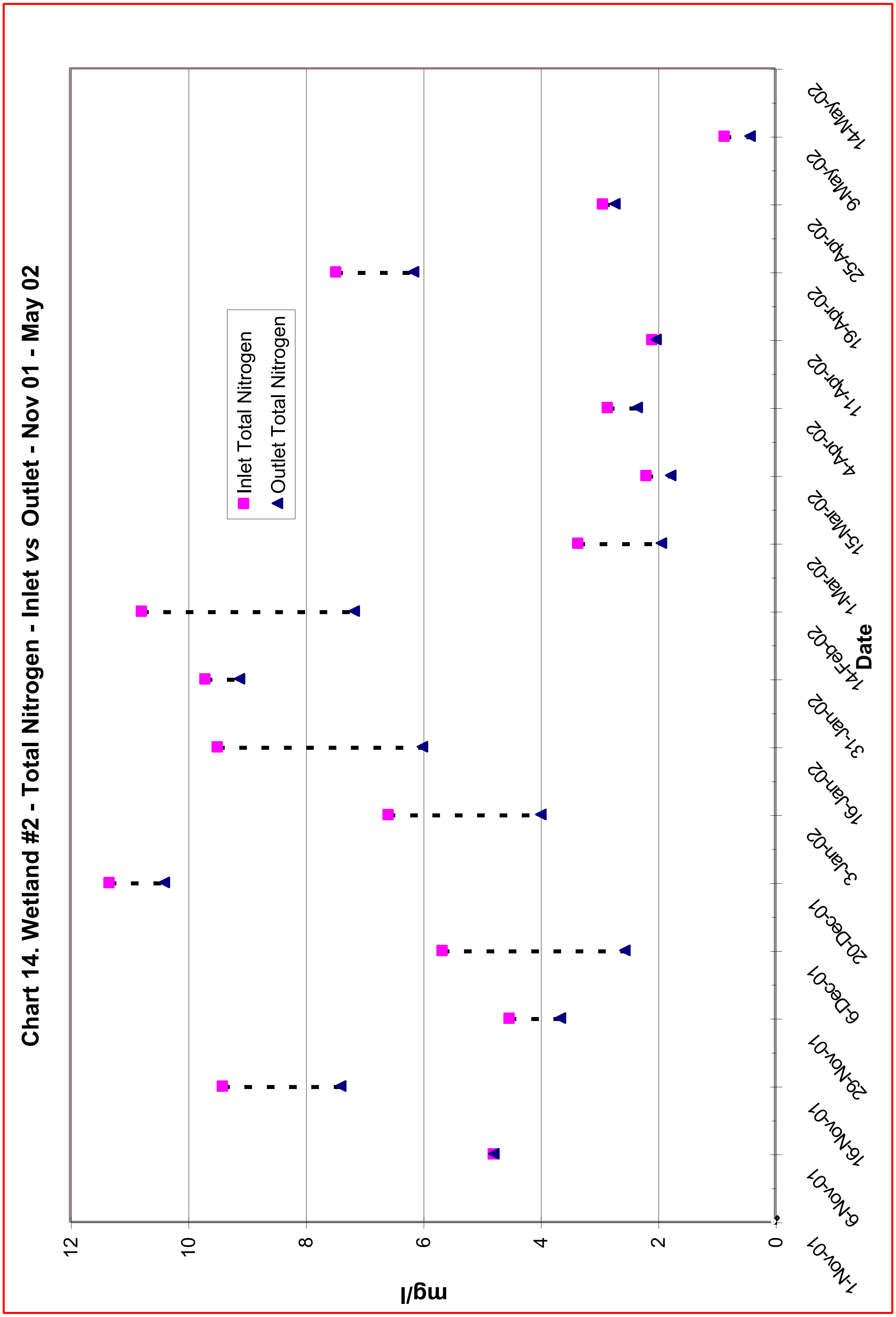
Chart 14. Wetland #2 - Total Nitrogen - Inlet vs Outlet - Nov 01 - May 02
Inlet Total Nitrogen
Outlet Total Nitrogen
mg/l
0
2
4
6
8
10
12
Date
1-Nov-01
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
14-Feb-02
1-Mar-02
15-Mar-02
4-Apr-02
11-Apr-02
19-Apr-02
25-Apr-02
9-May-02
14-May-02

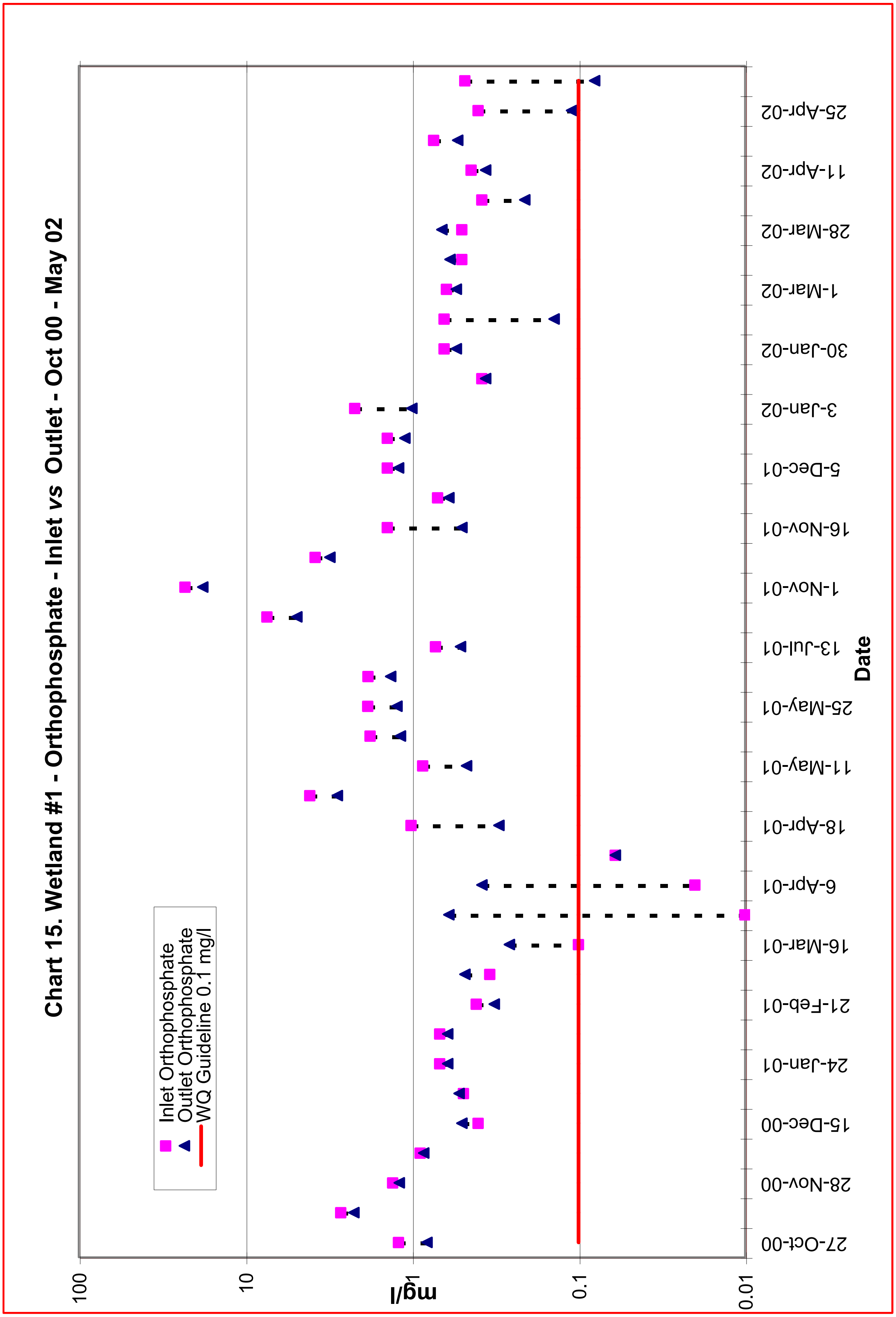
Chart 15. Wetland #1 - Orthophosphate - Inlet vs Outlet - Oct 00 - May 02
Inlet Orthophosphate
Outlet Orthophosphate
WQ Guideline 0.1 mg/l
mg/l
100
10
1
0.1
0.01
Date
27-Oct-00
28-Nov-00
15-Dec-00
24-Jan-01
21-Feb-01
16-Mar-01
6-Apr-01
18-Apr-01
11-May-01
25-May-01
13-Jul-01
1-Nov-01
16-Nov-01
5-Dec-01
3-Jan-02
30-Jan-02
1-Mar-02
28-Mar-02
11-Apr-02
25-Apr-02

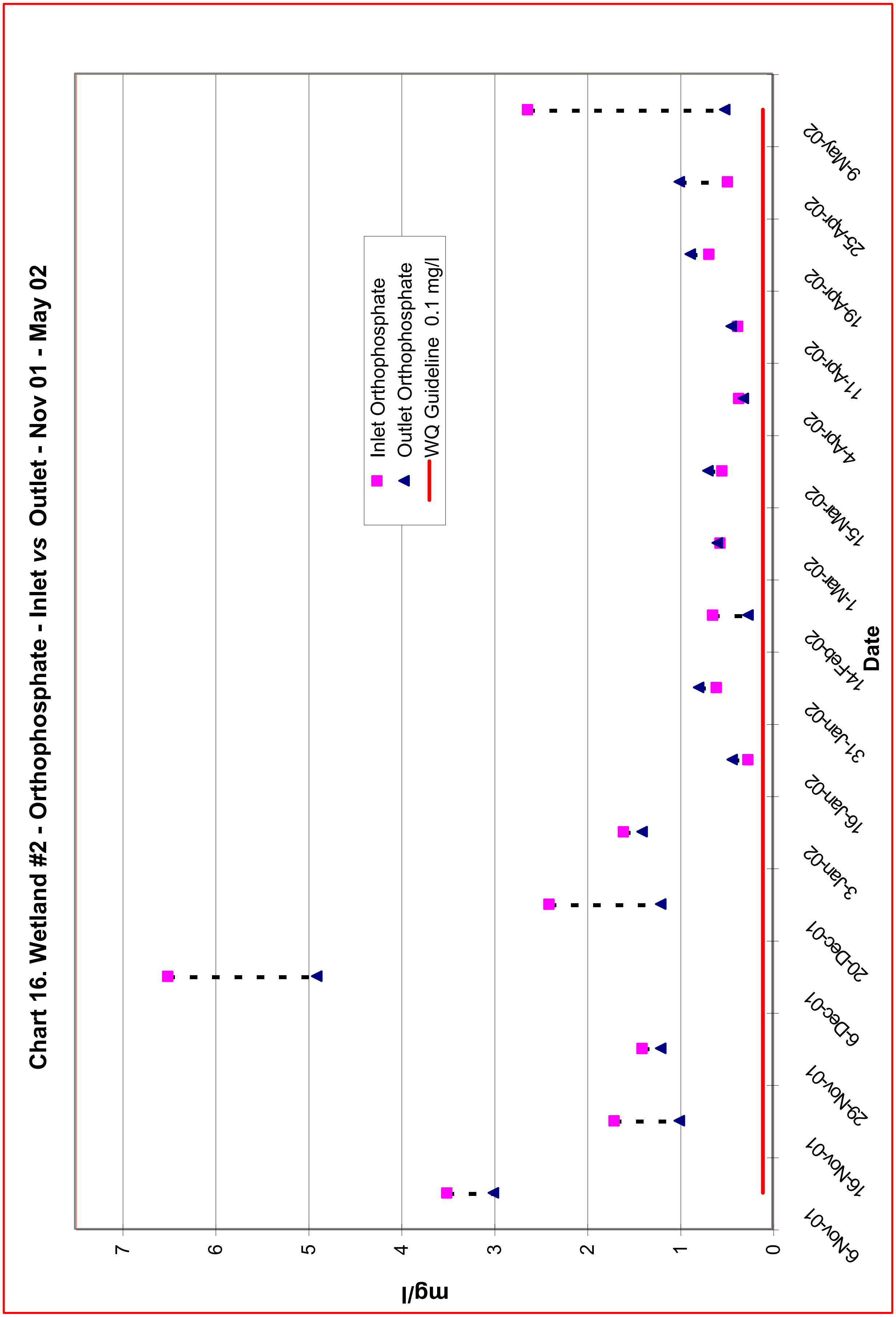
Chart 16. Wetland #2 - Orthophosphate - Inlet *vs* Outlet - Nov 01 - May 02
Inlet Orthophosphate
Outlet Orthophosphate
WQ Guideline 0.1 mg/l
mg/l
0
1
2
3
4
5
6
7
Date
6-Nov-01
16-Nov-01
29-Nov-01
6-Dec-01
20-Dec-01
3-Jan-02
16-Jan-02
31-Jan-02
14-Feb-02
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25-Apr-02
9-May-02

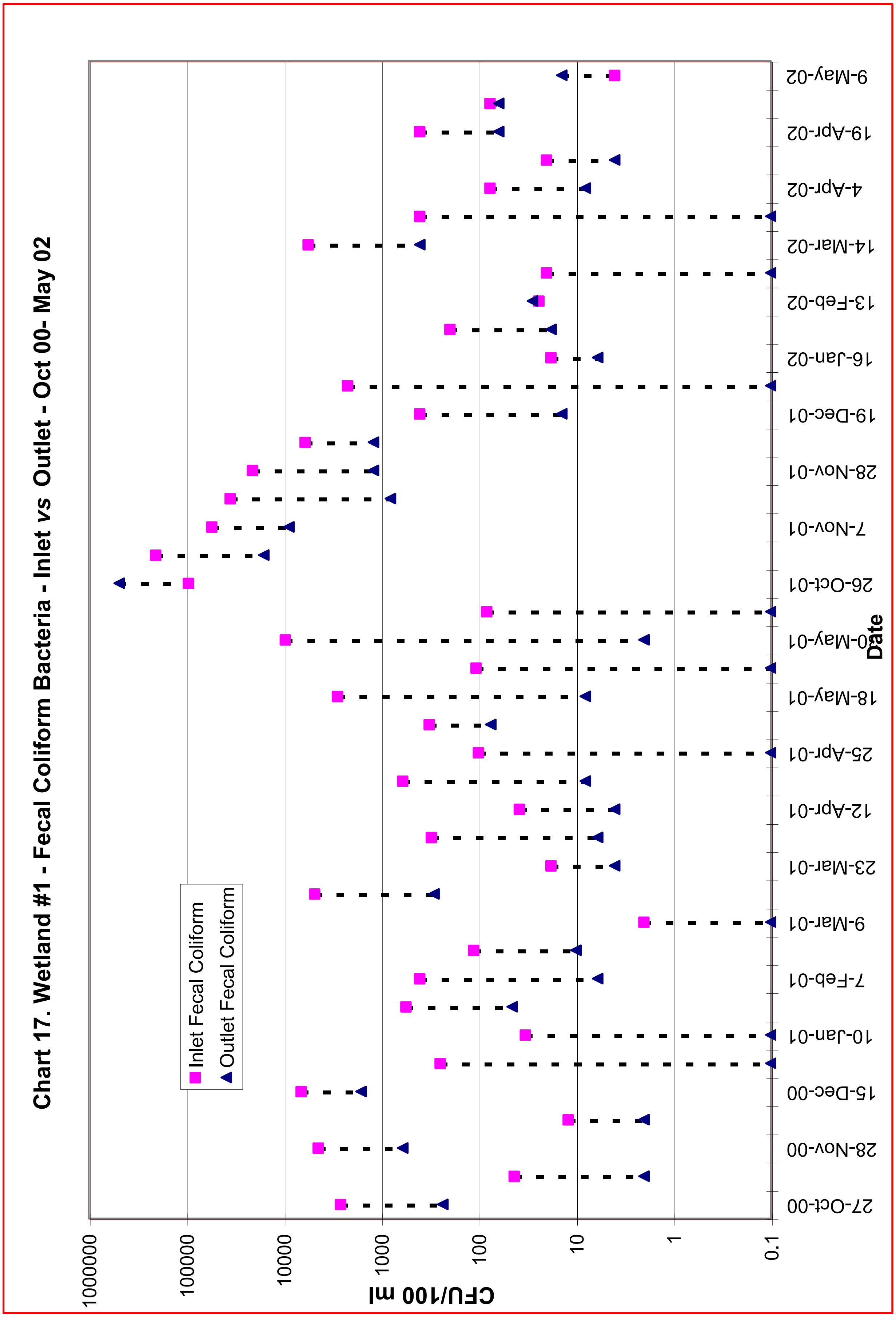

Chart 17. Wetland #1 - Fecal Coliform Bacteria - Inlet vs Outlet - Oct 00- May 02
Inlet Fecal Coliform
Outlet Fecal Coliform
CFU/100 ml
1000000
100000
10000
1000
100
10
1
0.1
Date
27-Oct-00
28-Nov-00
15-Dec-00
10-Jan-01
7-Feb-01
9-Mar-01
23-Mar-01
12-Apr-01
25-Apr-01
18-May-01
0-May-01
26-Oct-01
7-Nov-01
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9-May-02

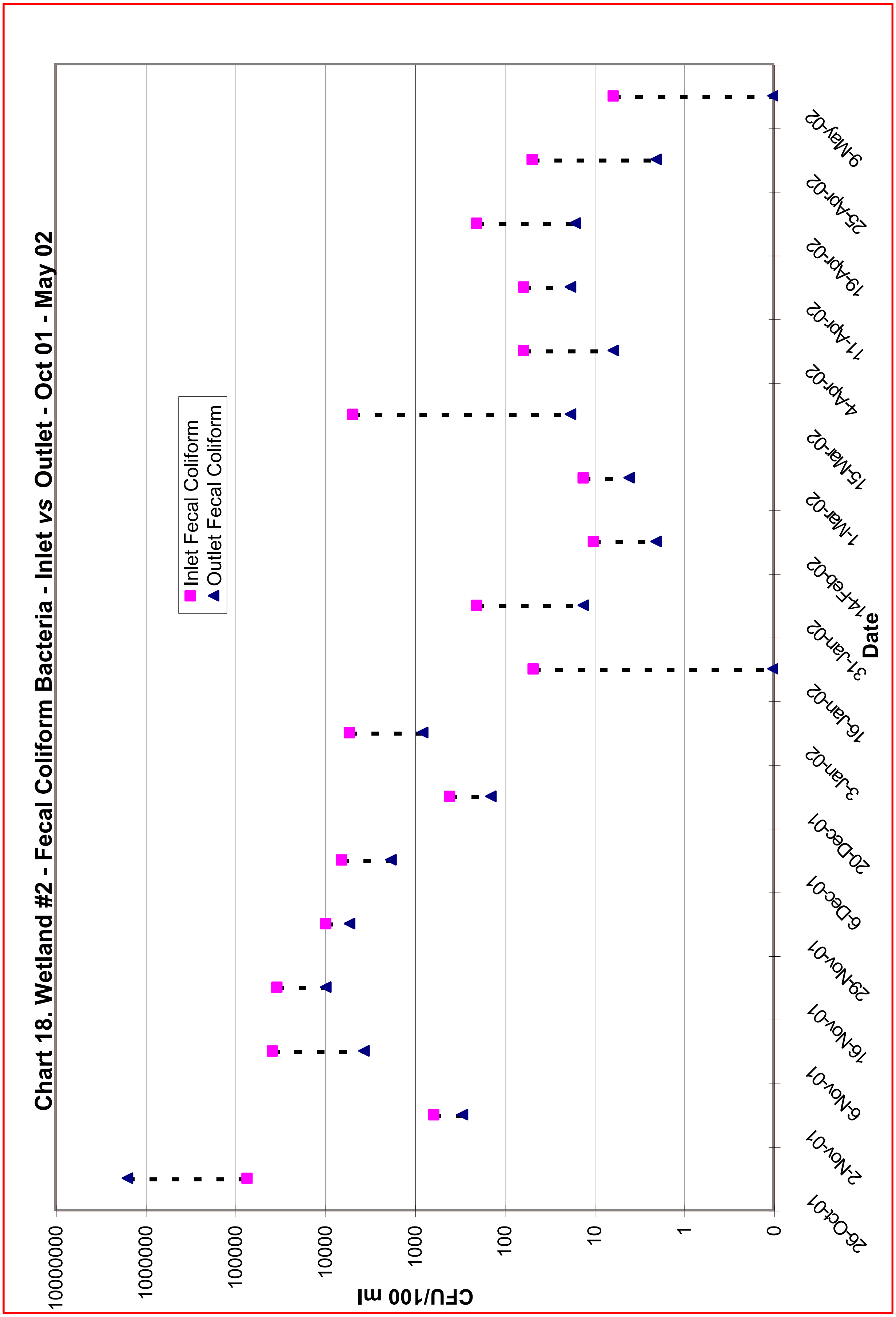

Chart 18. Wetland #2 - Fecal Coliform Bacteria - Inlet *vs* Outlet - Oct 01 - May 02